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# FINAL TECHNICAL REPORT

## Systems Engineering and Technical Assistance in Support of Digital Gallium Arsenide Insertion Projects

**Sponsored by:**
**Defense Advanced Research Projects Agency**
**Microelectronics Technology Office/Defense Sciences Office**
**Digital Gallium ArsenideTechnology Insertion Program**
**ARPA Order No. 6576**
**Issued by DARPA/CMO under Contract No. MDA972-89-C-0035**



Prepared By:

Daniel H. Butler, Jr.

Approved By:

Robert R. Swistak

30 April 1992

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**Booz•Allen & Hamilton, Inc.**



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DARPA

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## Booz•Allen & Hamilton, Inc.

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# EXECUTIVE SUMMARY

Booz•Allen & Hamilton Inc. provided Systems Engineering and Technical Assistance (SETA) to the Program Manager of the Digital Gallium Arsenide (GaAs) Insertion Program of the Defense Advanced Research Projects Agency (DARPA). Under this contract, Booz•Allen assisted DARPA's GaAs Program Manager in the execution of all 11 funded projects in the Digital GaAs Insertion Program (see Exhibit 1). These projects included upgrades to the following systems/subsystems:

- AN/ALQ-126 B ECM Set
- AN/ALQ-136 ECM Set
- OH-58D Kiowa Scout Helicopter Mast Mounted Sight
- P-3C Long Range Patrol Aircraft ISAR Radar
- E-2C Airborne Early Warning Aircraft (feasibility study only)
- Classified Spacecraft
- Army Tactical Radios
- V-22 Osprey (feasibility study only)
- RC-135 Distributed Array Processor
- RF Hellfire Missile Seeker

Many of the taskings accomplished under this contract required technical and programmatic evaluation of proposed GaAs insertion projects, including early involvement in assisting in the selection of the projects listed above. In providing this support, Booz•Allen developed a broad based methodology for technology insertion. Over the three and a half year period of this contract, the technology insertion methodology was applied to many candidate insertion projects. It was refined with lessons learned as the selection process continued and, by the time the 11 GaAs projects were funded, Booz•Allen had developed, with DARPA, an established methodology applicable to a wide variety of technology insertion projects. The methodology focuses on seven questions:

1. Is the system fielded?
2. Does the system have a future?
3. Are there recognized deficiencies in the system?
4. Does the candidate technology correct any of the deficiencies?
5. Is the improvement significant?
6. Are the acceptance issues, such as perceived risks and costs, surmountable?
7. Are the appropriate parties interested?

The technology insertion methodology is described in greater detail in the second section of this report.

DARPA

# INSERTION DEMONSTRATIONS OF DIGITAL GaAs TECHNOLOGY

| COMPANY | SUBSYSTEM | PLATFORM AND APPLICATION | GaAs PAYOFF |
|---|---|---|---|
| ***INTELLIGENCE AND SURVEILLANCE*** | | | |
| E-SYSTEMS | DISTRIBUTED ARRAY PROCESSOR | AIR FORCE RC-135 RECONNAISSANCE AIRCRAFT | PROCESS SIX TIMES AS MANY SIMULTANEOUS SIGNALS AT 300 LBS LESS WEIGHT |
| MARTIN MARIETTA | ON BOARD PROCESSOR | SPACECRAFT | INCREASE FROM 75 MOPS TO 560 MOPS WITH NO CHANGE IN SOFTWARE |
| TEXAS INSTRUMENTS | SIGNAL PROCESSOR | NAVY P-3C AN/APS-137 SURFACE SEARCH RADAR | SIGNIFICANT IMPROVEMENT IN ISAR IMAGE RESOLUTION |
| GRUMMAN | RADAR PROCESSOR | NAVY E-2C AN/APS-145 AIRBORNE EARLY WARNING RADAR | 45% GREATER RANGE; 35% SMALLER TARGETS IN CLUTTER; 40% FEWER FALSE TARGETS |
| ***WEAPONS AND COMBAT SUPPORT*** | | | |
| McDONNELL DOUGLAS | IMAGE PROCESSOR | ARMY OH-58D SCOUT HELICOPTER | TRACK-WHILE-SCAN; MOVING TARGET INDICATOR; MULTIPLE TARGET TRACKING |
| HONEYWELL | DIGITAL MAP COMPUTER | NAVY/MARINE CORPS TACTICAL A/C NAVIGATION | REAL-TIME MISSION REPLANNING; LOW-ALTITUDE TERRAIN AVOIDANCE |
| MARTIN MARIETTA | SIGNAL PROCESSOR | ARMY LONGBOW RF HELLFIRE MISSILE SEEKER | LOWER UNIT COST AT REDUCED WEIGHT AND VOLUME; IMPROVED LETHALITY |
| ***ELECTRONIC WARFARE*** | | | |
| KOR ELECTRONICS | DIGITAL RF MEMORY | NAVY ULQ-21 TARGET DRONE ECM | LOWER UNIT COST AND IMPROVED TRAINING REALISM |
| ITT AVIONICS | DIGITAL RF MEMORY | ARMY AN/ALQ-136 AIRCRAFT ECM | COUNTER NEW THREATS WITHIN WEIGHT AND POWER CONSTRAINTS |
| SANDERS ASSOCIATES | SIGNAL PROCESSOR | NAVY AN/ALQ-126B TACTICAL AIRCRAFT ECM | COUNTER NEW THREATS WITHIN WEIGHT AND POWER CONSTRAINTS |
| ***COMMUNICATIONS*** | | | |
| E-SYSTEMS | MODEM AND FREQUENCY SYNTHESIZER | ARMY AN/PRC-126 COMMUNICATIONS | ANTI-JAM FREQUENCY HOPPING; COMPATIBILITY WITH SINCGARS |

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**Exhibit 1**

Other support provided under this contract included:

- **Systems Analysis** – including analysis of all 11 funded GaAs insertion projects using the methodology introduced above
- **Support of Insertion Projects** – serving as liaison between DARPA, other government offices, and GaAs contractors; attending technical reviews; gathering data; assessing progress
- **General Systems Information** – including background information on technical and programmatic issues
- **Presentation Materials** – including over 200 view graphs and numerous briefings
- **Meeting Facilities** – organizing and providing facilities for meetings up to the SECRET level for up to 20 participants
- **Conference Organization** – supporting all aspects of conference planning for groups ranging from 20 to 200 participants.

Booz•Allen provided DARPA's GaAs Insertions Program Manager the responsive, comprehensive support necessary to run a smoothly operating DARPA program. The successes of this program are now being demonstrated, most recently with the flight test of a Navy P-3C search aircraft, upgraded with a GaAs processor in the AN/APS-137 radar. This technology insertion doubled the radar's image resolution while remaining within the system weight, volume, and power constraints. This insertion was accomplished in a remarkably short time frame of two and a half years. Booz•Allen is pleased to have been a contributor to this and other successes of DARPA's Digital GaAs Insertions Program.

# FINAL REPORT
# SYSTEMS ENGINEERING AND TECHNICAL ASSISTANCE IN SUPPORT OF DIGITAL GALLIUM ARSENIDE PROJECTS

## I. INTRODUCTION

Booz•Allen & Hamilton provided Systems Engineering and Technical Assistance (SETA) in support of Digital Gallium Arsenide (GaAs) Projects, for the period of performance from November 7, 1989 through February 29, 1992, under Contract No. MDA972-89-C-0035, ARPA Order 6576. Booz•Allen provided engineering analysis for system insertion efforts for digital GaAs and related technologies. After viable insertion candidates were chosen, Booz•Allen supported those projects under the guidance of the DARPA Program Manager for the Digital GaAs Program. Support included acting as liaison between the government and the GaAs contractors, arranging contractor reviews, providing meeting facilities, and producing presentation materials.

In order to achieve the goals established for the GaAs program, Booz•Allen developed a methodology for assessing the likelihood of success through technology insertion, including resolution of technical problems and gaining user support. This methodology is suitable for use with other technology projects, and, in fact, has since been used to judge the likelihood of successful insertion of optical processors. The methodology is discussed in detail in the second section of this report. Specific analyses and other tasks from the Statement of Work are discussed in the third section. The conclusion discusses the accomplishments under this contract and, more generally, of the Digital GaAs Insertion Program.

## II. INSERTION METHODOLOGY

### A. GOALS OF ADVANCED TECHNOLOGY INSERTION

The methodology for matching systems and technology is based on a set of common DARPA goals for technology insertion. Successful insertion programs help accomplish these goals:

**Goal 1: Achieve broad based acceptance of the new technology through demonstration.** Wide-scale implementation of a new technological development is impeded by such acceptance issues as lack of familiarity with and understanding of the technology; skepticism about cost and performance estimates; resistance to change; and the perception that implementing the technology will increase programmatic risk via schedule slippage, cost overruns, and even program cancellation. Within the military community, acceptance issues result in a reluctance to implement new technologies in either developmental or fielded systems. However, if an insertion program can demonstrate the new technology's reliability and sufficient level of maturity, the technology can be vaulted into "proven" status and wide-scale implementation may be possible.

**Goal 2: Reduce the time between technology development and acceptance.** Without a concerted effort, a 10-20 year evolutionary period normally transpires between the initial proof-of-principle and wide-spread acceptance and implementation of a new technology. Economic competitors of the United States have devised various ways to shorten this evolution time, such as coordinated industrial policies or government subsidies for commercial research and development. In this way Japan, Germany, and others have gained a competitive edge in many new technological areas by leading the global market in implementation and commercialization. Technology insertion, as a strategy to shorten the gestation period, is in keeping with U.S. free market economic policies. A primary goal of advanced technology insertion is to significantly reduce the time required to move technological developments from the drawing board to the assembly line. Experience in advanced technology insertion programs such as the Digital GaAs Insertion Program indicates that an accelerated time frame of four years, or even less, is achievable. For instance, digital GaAs technology was in place in the Navy P-3C AN/APS-137 radar within 2 and a half years from the program's initiation and will be in the USAF RC-135 reconnaissance aircraft and the on-board processor for a classified spacecraft within 4 years. Insertions are generally designed to speed the transition of a technology to operational use, and such experience shows that they can shorten the time from lab to field from ten years to as little as four years. Thus, a four year goal has been established as a target for insertion projects.

**Goal 3: Achieve significant military payoff.** The goal of military acquisition programs, whether they develop new systems or upgrade existing programs, is to improve military capability. With current budget pressures reducing the number of new systems, upgrades to existing systems will become a more important way to maintain and enhance capabilities. Insertion of advanced technology presents an opportunity to provide some of the upgrades required in a cost effective manner, helping to ensure the continued superiority of U.S. weapon systems.

**Goal 4: Provide a domestic market demand for the new technology.** The development of a viable domestic industry is important, especially for technologies which become vital to the military. The U.S. should avoid future dependence on foreign sources for critical components. However, as with military users, new technologies face acceptance issues in the domestic economy. The main obstacle to commercialization is utility: insertion programs that demonstrate how the technology can be used for commercial products or processes spur the commercialization and industrialization of the new technology. Thus, in addition to demonstrating the feasibility of the technology and providing military payoffs, successful insertion programs can also lead to commercialization in the domestic economy. Additionally, a successful insertion into a military system generates military demand for the technology, which also encourages the development of a domestic industrial base.

## B. METHODOLOGY FOR SELECTING INSERTION CANDIDATES

The methodology itself addresses seven questions. The first five relate to fundamental technical and operational issues that effect whether the system is suitable for insertion; the last two focus on whether the user community will support the insertion. While the methodology does not include an absolute scale for weighting the questions, every question should be adequately considered before selecting a candidate system. Positive answers to all questions result in the best match between the technology and the system and the highest likelihood for successful insertion. The methodology focuses on these questions:

1. Is the system fielded?
2. Does the system have a future?
3. Are there recognized deficiencies in the system?
4. Does the candidate technology correct any of the deficiencies?
5. Is the improvement significant?
6. Are the acceptance issues, such as perceived risks and costs, surmountable?
7. Are the appropriate parties interested?

The following step by step description, replete with examples from the Digital GaAs Insertion Program, demonstrates how the methodology can be applied to select the most appropriate systems for technology insertion. Exhibit 1 on the following page, **Technology Insertion Methodology**, illustrates the methodology. The following section discusses each question in depth, describing how methodology is applied to insertion candidates at each step.

**1. Is the system fielded?** There are several reasons for preferring fielded systems over developmental systems for technology insertion. With a fielded system, a four-year insertion goal is less threatened by outside factors, which are more numerous and consequential in developmental systems. For instance, developmental systems tend to be more susceptible to schedule slippage, unrelated technical risks, and changes in system configuration. These factors may combine to delay or even cancel the fielding of the new system. The possibility exists that delayor cancellation may be blamed on the new insertion technology.

In addition to being less susceptible to outside factors, and thus lower risk insertion candidates, fielded systems which incorporate new technology clearly demonstrate performance advantages. The baseline performance of the fielded system is already established before the technology insertion. Thus, the new technology inserted through an upgrade is likely to attract more attention in a fielded system and increase the visibility of the technology and the benefits it offers.

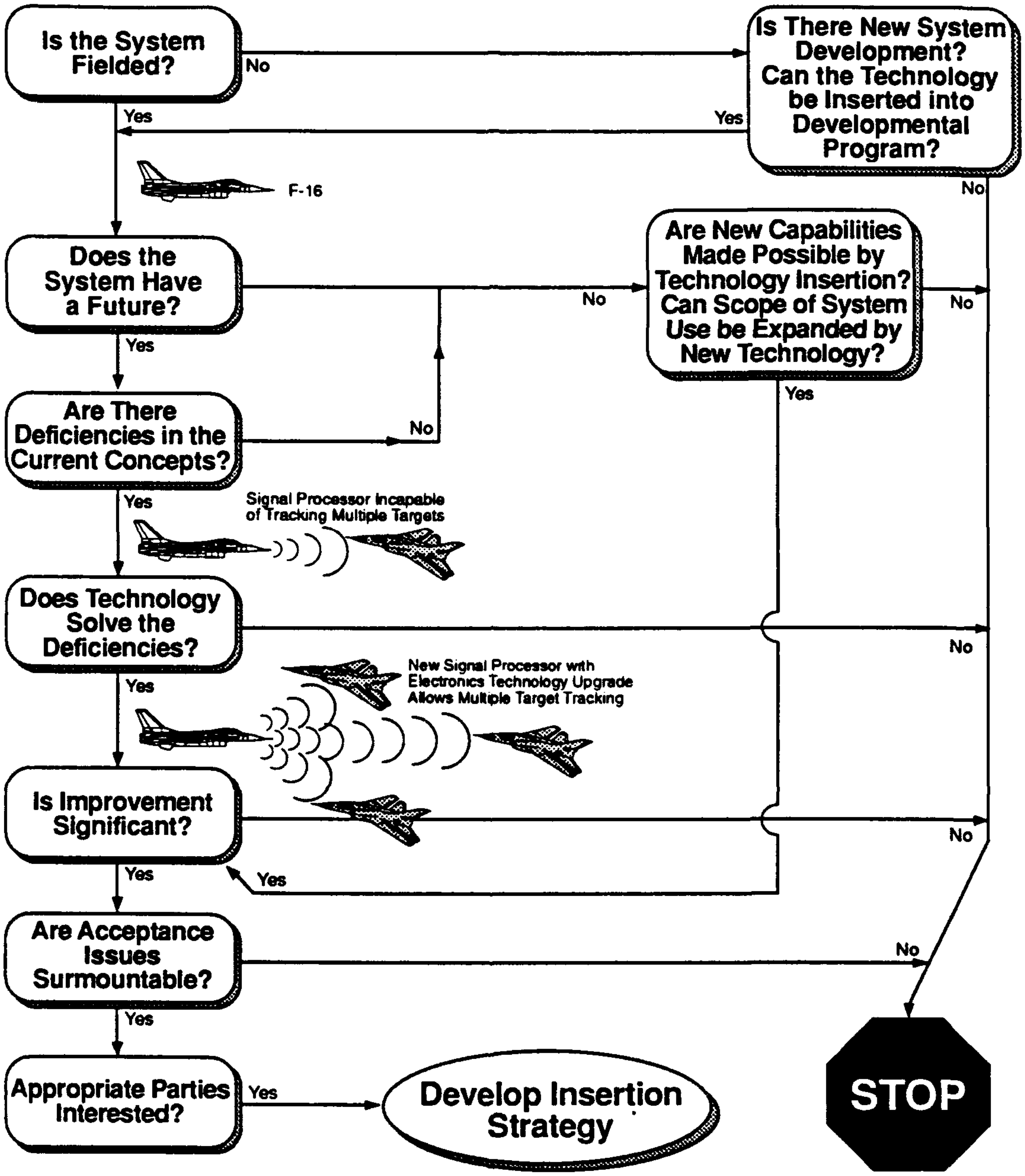


**Exhibit 2: Technology Insertion Methodology**

Another reason to select fielded systems is that they are much more likely to possess recognized deficiencies, which can be directly corrected by the new technology, than developmental systems. The strategy of upgrading fielded systems is gaining momentum in this era of declining defense budgets and reduced force structure. Such upgrades can maintain force effectiveness without the much larger expense of new system development.

However, technology insertions into developmental systems can, in some cases, have important advantages. The key advantage of working with developmental systems is design flexibility. Flexibility mitigates system-level integration issues and allows for a more optimal sub-system design. The same integration issues which might upset the feasibility or cost-effectiveness of an insertion into a fielded system might be surmountable with an insertion into a developmental system. Furthermore, with a developmental system, changes in system design can be accomplished without incurring the costs of having to retrofit fielded hardware.

Developmental systems can also provide greater opportunities to leverage new technology. With a fielded system, the insertion will generally be limited to a specific sub-system, while the overall system design remains unchanged. In many cases, if the overall system design could be altered to take maximum advantage of the technology, significantly greater benefit would accrue; but such flexibility is usually unaffordable in fielded systems.

A critical issue, however, when inserting technology into developmental systems is ensuring schedule compatibility between the insertion project and the developmental system. They should proceed on parallel paths so that at some well-defined decision point, the system manager can opt to insert the new technology with minimum disruption.

**2. Does the system have a future?** A system's official mission requirements determine whether a system has at least a 10 year future. Obvious, immutable mission requirements, such as the air defense mission of the F-16, and more subtle missions, as well as those subject to change, should be considered in devising a technology insertion strategy.

If a system is replaced during an upgrade, this will either abolish the insertion effort or force it to be redefined. Even if the insertion project can be transitioned to the replacement (developmental) system, the evolution period is likely to be extended. The insertion of a GaAs digital RF memory into the Army AN/ALQ-136 Aircraft ECM system is an example. After the insertion project began, the Army initiated an effort to completely replace the ALQ-136. Although the insertion effort has been transitioned to the replacement system, the Advanced Radar Threat Jammer (ARTJ), a four-year insertion goal will not be achieved. However, the successful demonstration of a GaAs-based update has influenced future system design of the ARTJ and the new technology will be incorporated.

Documented mission requirements can be obtained from the Office of the Secretary of Defense for Program Analysis and Evaluation, which maintains official information on requirements and procurement. The strongest case for an insertion program can be made if it is clear that the system's mission requirements have a future, no complete replacement is possible, and no other existing system's role could be expanded to meet the requirements.

**3. Are there recognized deficiencies in the system?** Insertion strategies need to provide solutions to recognized system deficiencies to demonstrate value added, especially during this time of declining Defense budgets, when the Services have less interest in upgrading systems which generally meet all of their current and foreseeable mission requirements. Identifying a deficiency requires research into the current and future operational role and capabilities of the system and its threats. The following insertion projects demonstrate how technology insertion can be used to solve recognized deficiencies.

- The helicopter-mounted ALQ-136 is currently unable to jam certain advanced threat radars, which have become prevalent on the modern battlefield. A GaAs digital radio frequency memory (DRFM) can provide the necessary capability within the weight and power constraints imposed on the system, while an equally capable silicon DRFM cannot be built within the system constraints.

- The Navy P-3C long range patrol aircraft's AN/APS-137 radar is unable to identify vessels at a range comparable to the range at which it can detect their presence; thus, the P-3C frequently has to deviate from its search pattern in order to visually identify detected vessels. Improving the radar's image resolution requires a faster signal processor. A GaAs signal processor provides this increased speed, doubling the radar's image resolution while remaining within the system's weight, volume, and power constraints. Current silicon technology cannot offer similar results.

- The Navy E-2C airborne early warning aircraft's AN/APS-145 radar cannot detect objects traveling above certain speeds and has significantly less detection range over land than over water. To correct these and other problems, a GaAs processor could provide the required computing capability within the system constraints, while a silicon processor cannot.

System deficiencies become apparent in several ways. For instance, an unanticipated technological advance in a threat system creates new requirements. While the process of determining mission requirements occurs continuously, the development, fielding, and support of military systems is a multi-year process. The threat environment projections which guide the formulation of system requirements are made, on average, four to seven years prior to fielding the system. If the threat has increased beyond earlier assessments, a recognized deficiency may result before the system is scheduled for replacement.

Another way to identify a deficiency is to investigate whether a scheduled replacement system has been delayed. If so, the difference in the capabilities between the current system and its replacement may reveal deficiencies.

Replacement system delays can result from budgetary concerns or programmatic complications, even though a military requirement for the improved system may still exist. Depending on the length of the delay and the probability of program cancellation, the system scheduled to be replaced may be a candidate for upgrade via technology insertion because it still has a 10+ year future.

In addition to correcting a recognized deficiency, the insertion of new technology may provide new mission capabilities for a system. For example, the introduction of cruise missiles provided a new strategic mission for the B-52 bomber. Although cruise missiles did not restore the B-52's ability to perform its original strategic mission of penetrating Soviet airspace (one of its recognized deficiencies), or preclude the requirement to develop replacement systems (i.e., the B-1 and B-2), cruise missiles on the B-52 contributed to the strategic requirement for multiple weapon delivery modes.

Note: If a potential insertion does not address a recognized deficiency but provides new mission capabilities for a system, then the next step in the methodology, question 4, should be skipped.

**4. Does the candidate technology correct any of the deficiencies?** Operational gain at the system level is the key parameter in determining the value of an insertion. While a new technology can often provide impressive performance gains at the sub-system level, there may be no operational gain at the system level, where performance really matters. Determining if the insertion will correct the system-level deficiency requires analysis by experts who understand how the upgraded sub-system will influence the performance of the overall system. For example, a GaAs insertion upgrade was proposed to improve, by a factor of 10, the accuracy of the laser range-finder used by Army artillery units. However, the random delivery error of the artillery shells (which is independent of the aim point) was much greater than the aiming error, and a simple analysis proved that the probability of hitting a target (i.e., the deficiency) would not have been measurably improved by the insertion of the GaAs technology.

In some cases, a proposed insertion may require substantial changes in the configuration of the current system or even the building of a completely new system, in which case the system is not a preferred candidate for insertion. For instance, the proposed insertion of a GaAs processor into the AN/APS-145 radar for the Navy E2-C could not provide the desired improvements without essentially rebuilding the radar. As a result, the insertion of an improved sub-system (i.e., the processor) could not by itself correct the system-level deficiencies and the project was discontinued.

**5. Is the improvement significant?** It is essential to know whether or not the proposed insertion will provide a significant operational benefit. An operational analysis, using quantifiable measures of merit, is necessary to assess whether the potential benefits sufficiently outweigh the costs to justify inserting new technology.

Common measures of merit include survivability increase, system and force exchange ratios, probability of kill, systems lost, and cost savings. The selection of measures of merit should be based on system missions and the priorities of the user Service.

The analysis should be thorough enough to satisfy decision makers that a significant operational benefit can be demonstrated. Later, after the insertion candidate has been selected, more detailed analyses may be required to support advocacy efforts. A Cost and Operational Effectiveness Analysis (COEA) should be performed before any upgrade is approved. But at this stage, the level of detail varies with the difficulty of isolating and quantifying a significant operational benefit. Any analysis should compare the baseline, upgraded, and any competing versions of the system, or other systems that could perform the same mission.

In some cases, it may be difficult or impossible to predict whether the anticipated improvements will be considered sufficiently significant by the user Service. It may be necessary to proceed to the next steps in the methodology before the significance of the improvement is known.

Cost is another important improvement that an insertion can achieve. Clearly, cost implications are always significant to the user Service, whether or not cost savings represent the greatest benefit. A potential insertion has favorable cost implications if it reduces costs while providing the same capability, or adds new or greater capability to a system more cost-effectively than any other feasible option, or both. As mentioned earlier, a COEA should be performed before an insertion takes place. Therefore, it is important to ascertain, in advance and with sufficient certainty, the direct and indirect cost implications.

Important categories to investigate when identifying cost benefits include manufacturing costs, retrofit costs, indirect cost benefits from operational payoffs, and maintenance and support costs. For developmental and in-production systems, a manufacturing cost analysis should be performed to estimate the production cost of the upgraded sub-system. This cost analysis is usually performed by the hardware manufacturer. If the estimated cost of the sub-system can be reduced to the extent that the cost of the entire system also drops significantly, then this benefit alone might create sufficient user interest to support insertion. A 50% production cost savings estimate for the Navy ULQ-21 Target Drone's electronic countermeasures suite, resulting from the insertion of a GaAs digital RF memory, was the compelling benefit for the ULQ-21 insertion.

A direct operational benefit may provide a significant indirect cost benefit. If the insertion of a new technology can reduce the number of systems required to perform a mission, this reduces operational costs. It may even reduce the number of systems which must be fielded. An example: operational analysis indicated that the insertion for the P-3C long range patrol aircraft would reduce the number of sorties required to search a given area of ocean, thus reducing the operational costs per search and potentially reducing the number of aircraft necessary (so fewer aircraft would have to be procured).

An insertion might provide significant cost benefits by diminishing the maintenance and support requirements for a system. If the reliability or longevity of a sub-system can be increased, then repair or replacement costs are reduced. And if the rate of availability of a system can be increased, due to speedier repair or greater reliability, then fewer systems may have to be built. For example, the requirement for an Air Force wing stipulates that 72 aircraft be ready to fly at all times. To accomplish this, approximately 100 aircraft are needed, with most of the 28 remaining aircraft undergoing some type of maintenance. A higher rate of availability could reduce the number of extra aircraft necessary to ensure that 72 aircraft are ready to fly at all times. This, in turn, could lead to fewer aircraft being built.

If another technology can provide the same capabilities as the proposed insertion, then the cost implications of the competing technologies should be evaluated. For example, a GaAs insertion was proposed to enhance a USAF airborne targeting system. The candidate insertion would have provided an automatic target recognition capability to a developmental system soon to enter full scale production. The potential payoff of the insertion would have been an increase in a number of targets that could be attacked per pass. The initial steps of this methodology were carried out and the results were favorable. Research confirmed that there was a recognized need to increase the number of targets that can be engaged during a single aircraft pass. This requirement formed, in part, the rationale for the USAF's Modular Standoff Weapon program and the Navy's Advanced Interdiction Weapon System program. The proposed insertion was complementary to those developmental programs and was also applicable to weapons currently in the Air Force inventory.

Operational analysis indicated that the projected automatic target recognition capability could result in a threefold increase in the number of targets killed per weapon delivery pass, with a proportionate reduction in aircraft attrition per sortie. The reduced attrition rate allowed for a substantial increase in the total number of sorties that can be generated during a prolonged air campaign. But the investigation of alternate technology solutions revealed that the necessary improvement in processing capabilities could be achieved using current silicon (CMOS) technology, which involved less cost risk than GaAs. The proposed GaAs insertion was dropped from consideration.

**6. Are acceptance issues surmountable?** The necessity for new technology to gain acceptance by users cannot be overstated. On July 25, 1991, Stephen K. Conver wrote a memorandum to the Under Secretary of Defense (Acquisition) addressing his ideas on improving the Defense Acquisition Process:

"The requirements process is sometimes at cross-purposes with the acquisition process....'Push/pull' -- the reluctance of some users to accept new technology that must be 'pushed' or sold to them, in contrast to the familiar technology, which they willingly 'pull' into their organizations."

Technology insertions, properly executed, can overcome this understandable reluctance on the part of users.

An important aspect of the insertion strategy, therefore, is risk minimization, as apprehensions about acceptance issues may block insertion, if not properly appreciated in planning efforts. The three most common issues are technical risk, cost risk, and the r.turn on investment. A robust risk analysis, involving cost, schedule, and performance issues, may be needed if acceptance issues and risk are perceived to be significant.

Another way to reduce risk is to pursue an alternate development path and acquisition strategy. For example, two established strategies are the acquisition policies of Evolutionary Acquisition and Preplanned Product Improvement. Evolutionary Acquisition is an approach in which a core capability is fielded and the system design has a modular structure with provisions for future upgrades and changes. If the insertion does not effect the core capability, then failure to overcome risks will not prevent initial fielding of the system or the eventual insertion. The F-16 is an example of an evolutionary acquisition. It has been upgraded numerous times and several programs are in place to test and integrate new technologies into the aircraft. Preplanned Product Improvement is a phased approach that incrementally satisfies operational requirements in order to address cost, technical risk, or relative time urgency while the deferred element is developed in a parallel or subsequent effort.

**7. Are the appropriate parties interested?** The appropriate parties usually consist of the controlling organization responsible for the "care and feeding" of the system, the operational units which operate the system, and the relevant contractors, minimally including the sub-system manufacturer. Controlling organizations would include the Air Force Logistics Command (AFLC), which controls fielded aircraft; NAVSEA, for fielded naval vessels; and NAVAIR, for fielded naval aircraft. The operational units and the controlling organization work closely together to identify and evaluate potential upgrades. In a successful insertion project, it is essential to obtain the interest of the operators. The controlling organization will generally concur with the operational units if the operators are not interested. Since the insertion project must involve the sub-system manufacturer, and often other contractors, their interest is also critical.

Because of the difficulty in securing system sponsorship of new technology, many government funded technology development programs traditionally opt to build generic sub-system prototypes which achieve a "next generation level of performance." The user community is then invited to take the initiative to implement the technology. However, a new approach, based on negotiated commitments, has proved extremely successful. The key to this new approach is to negotiate a prior agreement from the user Service. The Service would agree to endorse an upgrade to the system if a successful demonstration of the new technology, inserted into the military system, is accomplished within negotiated time and performance guidelines. Commitments of this type have resulted in GaAs insertion upgrades to an on-board processor for a classified spacecraft, the AN/APS-137 radar for the Navy P-3C, and the image processor for the Army OH-58D helicopter.

Another important element of this approach is to persuade the user Service and the appropriate hardware manufacturers to share the cost of the project. If the user Service demonstrates its support, the hardware manufacturers may opt to share costs to develop a proprietary capability or demonstrate their commitment. an example of this type of user commitment is the upgrade to the RC-135 distributed array processor. When the contractor ran into technical difficulties that resulted in a significant cost overrun, the user agreed to pay the additional costs because of the greatly improved operational benefits promised by the GaAs processor.

Development of this insertion methodology was of great benefit to the GaAs program. By using the methodology, program managers were able to identify suitable candidates for insertion. Booz•Allen helped to analyze the likelihood of success and benefits from the proposed insertion. Booz•Allen also provided support for the insertion projects as well as technical and administrative support to the MTO/DSO staff involved on the project. This support has been broken down into specific categories based on the statement of work for the Digital GaAs SETA contract, and is further described and explained below.

## III. SUPPORT UNDER EACH TASK IN THE STATEMENT OF WORK

### A. SYSTEMS ANALYSIS

Booz•Allen conducted quantitative and qualitative analyses of system and mission requirements as they pertained to the potential insertion of advanced electronics into a wide range of military systems. This analysis involved evaluating alternatives, trade-offs, costs and benefits, and investigating compatibility, interoperability, and reliability issues. Fulfilling this task required research, analysis, and computational support. System analyses were performed on a wide range of military systems, including all those selected for GaAs technology insertion. The following military systems were researched in-depth to determine suitability for digital GaAs upgrades:

1. AN/ALQ-126 B ECM Set
2. OH-58D Kiowa Scout helicopter
3. P-3C Patrol Aircraft
4. E-2C Airborne Early Warning Aircraft
5. An/SLQ-32 ECM Set
6. Ground/Vehicular Laser Locator Designator
7. Special Operations Forces Aircraft
8. Army and Navy Tactical radios
9. V-22 Osprey

Research included examination of contractor proposals; data gathering from industry, government program offices, and academia; and research using unclassified data bases. The following examples of operational analyses illustrate the kind of mission and system analyses performed by Booz•Allen.

1. *AN/APS-145 Radar on E-2C Airborne Early Warning Aircraft* – Booz•Allen performed operational analyses on two scenarios. One posited an attack on a guided missile frigate (e.g., USS Stark) operating in the Persian Gulf; the second, a Soviet Backfire raid versus an aircraft carrier battle group. Three system improvements were examined: increased target detection range, detection of targets traveling faster than Mach two, and increased small target detection capability. Results of these analyses showed a marginal payoff due to increased target detection range, little to no payoff for high-speed target detection, but significant payoff if small target detection probabilities can be achieved. The results of this analysis confirmed what were reported to be the Navy's upgrade requirements – improved small target detection capability. From a military utility basis, this analysis determined that the insertion project was warranted. This project was not pursued beyond an initial feasibility study because of insufficient user commitment due to the user's uncertainty about the future of the platform.

2. *SLQ-32 DRFM* – An operational analysis was performed on an aircraft carrier group being attacked by two regiments of Soviet Backfire bombers plus other supporting Soviet aircraft. Dramatic improvements in carrier survivability were shown to be the result of the digital GaAs insertion (DRFM) in the SLQ-32 shipborne radar jammer set. Survivability could be increased from 20% to 90% as a result of the greatly decreased burn through range. The results of this analysis indicated that this upgrade project was warranted because of military utility. This project was not pursued by DARPA because of high technical risk associated with proposed related silicon developments; the GaAs development was deemed to be a low risk technology development.

3. *Ground/Vehicular Laser Locator Designator* – In an operational analysis of this system, analysts discovered that the proposed digital GaAs upgrade would improve the system's range measurement accuracy error from ten meters to one meter. However, no appreciable improvement in artillery fires would occur since the inherent inaccuracies of artillery fires are so much greater than the errors associated

with estimating the range from the artillery observer to the target. The results of this analysis indicated that this upgrade was not warranted.

In addition, Booz•Allen researched and provided background material on U.S. military command, control, communications, and intelligence ($C^3I$) systems. The research focused on hardware and software systems, functions, procedures, and operations. A briefing on the interactions between the DARPA Digital GaAs Insertion Program and $C^3I$ systems was prepared for a DARPA presentation in February 1989.

## B. SUPPORT OF INSERTION EFFORTS

Booz•Allen provided extensive support for the 11 selected digital GaAs insertion projects. Booz•Allen functioned as a liaison between DARPA, relevant government program offices, and the GaAs contractors. Booz•Allen's program manager, Dan Butler, traveled extensively to all GaAs contractors in order to attend frequent preliminary design reviews and in-progress reviews. He collected and reduced demonstration data from these trips and provided the data in a framework for interpretation to DSO/MTO. Several trip reports are attached to illustrate this kind of support and analysis.

As part of the insertion methodology described in Section II, a new approach to secure system sponsorship of new technology was developed. Rather than building a generic subsystem and inviting users to implement the technology, this approach involved negotiating prior commitments from user services to endorse the upgrade if the new technology was successfully demonstrated in the military system within time and performance guidelines. Agreements of this type were instrumental in many of the GaAs insertion projects. This approach gave the GaAs contractors the advantage of designing upgrades for systems which were already operational. The project could be brought to the field sooner and compared in performance to the known preceding technology. In addition, it reassured the contractor that there would be a market for the product if the demonstration was successful.

For all the selected projects, Booz•Allen helped develop funding justifications and tracked contract and financial milestones. Technical and financial data bases on each project were developed, participants in the insertion programs were queried and the responses were collected and processed. The results were then delivered to DSO/MTO staff; sample pages showing the presentation of the data are attached.

Also, Booz•Allen provided effective materials for press releases relating to the Digital GaAs Insertion Program. Booz•Allen's Corporate Communications Department drafted the news releases, and the Booz•Allen program manager compiled program fact sheets for distribution to key publications and journalists. In addition, technical and management data were converted into reports and articles for publications (e.g., "Digital Gallium Arsenide (GaAs) Upgrades for Improved Military System Capabilities," 1989). Finally, Booz•Allen maintained a program library, cataloging and storing relevant information for each GaAs insertion project contract in hard copy files and computer data bases.

### C. GENERAL SYSTEMS INFORMATION

Booz•Allen provided background information on technical and programmatic aspects of a wide variety of operational and developmental military systems as required by MTO/DSO staff. Government and private sector developments relating to the entire field as well as selected insertion projects were tracked. Literature searches were conducted and material collected on a number of different programs, companies, and technologies. Fact sheets were then produced; copies of examples are attached.

In addition, Booz•Allen completed a survey of academia, industry, and potential users to discover high-payoff insertion opportunities for ceramic materials. Several application areas where significant system problems exist that could be solved with ceramics were identified, and an annotated briefing on the results of the ceramic insertion survey was prepared and delivered.

### D. PRESENTATION MATERIALS

Approximately 200 view graphs were produced, including high quality graphics such as photographic reproduction from a wide variety of original artwork and other materials. Some of these presentation aids required a very short turnaround time (e.g., one day or less). Camera ready copy was maintained and made available to DARPA so that additional copies could be made at low cost as necessary.

In addition to individual view graphs, various briefings were prepared throughout the period of the contract. Topics included selected insertion systems, the progress of GaAs insertion efforts, the AN/ALQ-126 upgrade, ECM effectiveness, etc. Brief presentations summarizing the progress of the program were made to the Gallium Arsenide Technology Review on April 24 - 27, 1989; the DARPA Systems and Technology Symposium, October 16 - 19, 1989; and other seminars and workshops.

These view graphs and briefings were logged and hard copies stored for rapid recovery as needed.

## E. MEETING FACILITIES

Booz•Allen provided conference facilities for meetings up to the SECRET level for groups of up to twenty people. Meetings of this type, however, only took place occasionally; a far greater level of support and effort was expended to support periodic conferences and workshops as described in the next section, Conference Organization.

## F. CONFERENCE ORGANIZATION

Booz•Allen provided administrative support for annual contractor reviews for up to 200 attendees. This included

- Drafting and distributing the agenda, including inviting speakers, and other attendees;
- Drafting and mailing preconference materials to attendees;
- Providing personnel to register and assist attendees during the meeting itself;
- Providing audio-visual equipment as needed;
- Collecting hard copies of all presentation materials, then copying and distributing that information to all attendees;
- Creating conference badges and insuring that all needed supplies are at the meeting (markers, note pads, and badge holders);

One of the first conferences supported by Booz•Allen under this contract was the annual Gallium Arsenide Review. For this review, 160 invitation packages were mailed to invitees. The mailing list of invitees was updated and computerized to include name, address, telephone number, and FAX number, and e-mail address. This list was maintained for use in future efforts.

Varying levels of support, depending upon DARPA guidance, were provided for numerous conferences and workshops throughout this contract. Extensive support was provided for the June 22, 1989, Electronic Warfare Conference, which included participants from the three funded insertion projects as well as interested users. Also, extensive support was provided to various DARPA GaAs Insertion Workshops and Reviews, which took place twice annually.

## IV. CONCLUSION

Over the three and a half year span of this contract, Booz•Allen provided a high level of technical support to DARPA in selecting projects and managing the Digital GaAs Technology Insertion Program. The methodology developed under this contract is suitable for application to projects involving different types of new technology. In exercising this methodology, systems, mission, and operational analyses and military benefit analyses were performed in order to select the most promising projects for GaAs technology insertion. Once these candidates were selected, Booz•Allen provided support to DARPA in monitoring the progress of these insertion projects. Booz•Allen personnel attended contractor briefings, preliminary design reviews and in-progress reviews, as well as setting up and supporting numerous workshops, briefings, and conferences. This included producing view graphs and other presentation materials in a short turn around time. In addition, a program library and files were maintained at Booz•Allen.

The DARPA Digital GaAs Insertion Program is a success. Through application of the insertion methodology described in the first section of this report, some systems which were considered promising candidates were shown to be unsuitable. For example:

- The proposed upgrade to the Army artillery laser range-finder was abandoned when analysis determined that the random delivery error of the artillery shells would negate any increase in target location accuracy derived from an order of magnitude improvement in range-finder insertion.

- In another instance, the proposed insertion of a GaAs processor into the AN/APS-145 radar for the Navy E-2C could not provide the desired improvements without essentially rebuilding the radar. Therefore, the insertion of an improved subsystem (i.e., the processor) could not by itself correct the system-level deficiencies and the project was discontinued, after an initial 6 month feasibility study.

- It was also discovered that a GaAs insertion project to enhance a USAF airborne targeting system could be achieved using current silicon technology, and at less cost risk than the proposed GaAs insertion, so that GaAs project was dropped from consideration as well.

A new approach to the insertion of technology was also developed by DARPA and supported under this contract. Rather than designing a generic subsystem and inviting potential users to implement the new technology, this approach depended on negotiating prior commitments from user Services. These Services agreed to endorse an upgrade if the new technology could be successfully demonstrated in an existing system within time and performance guidelines. This "commitment" approach contributed to a number of successful upgrades. Some of these are described below.

- The insertion of a GaAs digital RF memory into the Army AN/ALQ-136 Aircraft ECM has influenced the future system design of the Advanced Radar Threat Jammer (ARTJ), the system which will replace the ALQ-136.

- Successful insertion of a GaAs signal processor into the Navy P-3C search aircraft's AN/APS-137 radar doubled the radar's image resolution while remaining within the systems weight, volume, and power constraints. Digital GaAs technology was in place in the Navy P-3C AN/APS-137 radar within two and a half years from program initiation.

- Digital GaAs technology will be in place in the USAF RC-135 reconnaissance aircraft and the on-board processor for a classified spacecraft within 4 years of program initiation.

- Insertion of a digital GaAs RF memory into the electronic countermeasures suite for the Navy's ULQ-21 target drone resulted in an estimated 50% production cost savings for the ECM suite.

- A GaAs insertion upgrade to the image processor for the Army OH-58D helicopter vastly improved system performance, by adding important capabilities to the system.

Through its contract to provide systems analysis and technical assistance to DARPA, Booz•Allen played a part in this success. Throughout the contract period, Booz•Allen provided a high level of support for MTO/DSO staff, including systems analyses, support of insertion efforts, general systems information, presentation materials, and conference organization. The development of the insertion methodology has paid off with other technology applications as well. This SETA support enabled DARPA's Digital Gallium Arsenide Insertion Program Manager to efficiently run a successful program.

# APPENDIX 1

## Viewgraphs and Briefings

During the life of this contract, Booz•Allen produced nearly 200 separate viewgraphs and numerous briefings relating to aspects of the GaAs insertion program. Following are some examples of this work, especially viewgraphs relating to systems and operational analyses conducted by Booz•Allen.

# INSERTION DEMONSTRATIONS OF DIGITAL GaAs TECHNOLOGY

| COMPANY | SUBSYSTEM | PLATFORM AND APPLICATION | GaAs PAYOFF |
|---|---|---|---|
| *INTELLIGENCE AND SURVEILLANCE* | | | |
| E-SYSTEMS | DISTRIBUTED ARRAY PROCESSOR | AIR FORCE RC-135 RECONNAISSANCE AIRCRAFT | PROCESS SIX TIMES AS MANY SIMULTANEOUS SIGNALS AT 300 LBS LESS WEIGHT |
| MARTIN MARIETTA | ON BOARD PROCESSOR | SPACECRAFT | INCREASE FROM 75 MOPS TO 560 MOPS WITH NO CHANGE IN SOFTWARE |
| TEXAS INSTRUMENTS | SIGNAL PROCESSOR | NAVY P-3C AN/APS-137 SURFACE SEARCH RADAR | SIGNIFICANT IMPROVEMENT IN ISAR IMAGE RESOLUTION |
| GRUMMAN | RADAR PROCESSOR | NAVY E-2C AN/APS-145 AIRBORNE EARLY WARNING RADAR | 45% GREATER RANGE; 35% SMALLER TARGETS IN CLUTTER; 40% FEWER FALSE TARGETS |
| *WEAPONS AND COMBAT SUPPORT* | | | |
| McDONNELL DOUGLAS | IMAGE PROCESSOR | ARMY OH-58D SCOUT HELICOPTER | TRACK-WHILE-SCAN; MOVING TARGET INDICATOR; MULTIPLE TARGET TRACKING |
| HONEYWELL | DIGITAL MAP COMPUTER | NAVY/MARINE CORPS TACTICAL A/C NAVIGATION | REAL-TIME MISSION REPLANNING; LOW-ALTITUDE TERRAIN AVOIDANCE |
| MARTIN MARIETTA | SIGNAL PROCESSOR | ARMY LONGBOW RF HELLFIRE MISSILE SEEKER | LOWER UNIT COST AT REDUCED WEIGHT AND VOLUME; IMPROVED LETHALITY |
| *ELECTRONIC WARFARE* | | | |
| KOR ELECTRONICS | DIGITAL RF MEMORY | NAVY ULQ-21 TARGET DRONE ECM | LOWER UNIT COST AND IMPROVED TRAINING REALISM |
| ITT AVIONICS | DIGITAL RF MEMORY | ARMY AN/ALQ-136 AIRCRAFT ECM | COUNTER NEW THREATS WITHIN WEIGHT AND POWER CONSTRAINTS |
| SANDERS ASSOCIATES | SIGNAL PROCESSOR | NAVY AN/ALQ-126B TACTICAL AIRCRAFT ECM | COUNTER NEW THREATS WITHIN WEIGHT AND POWER CONSTRAINTS |
| *COMMUNICATIONS* | | | |
| E-SYSTEMS | MODEM AND FREQUENCY SYNTHESIZER | ARMY AN/PRC-126 COMMUNICATIONS | ANTI-JAM FREQUENCY HOPPING; COMPATIBILITY WITH SINCGARS |

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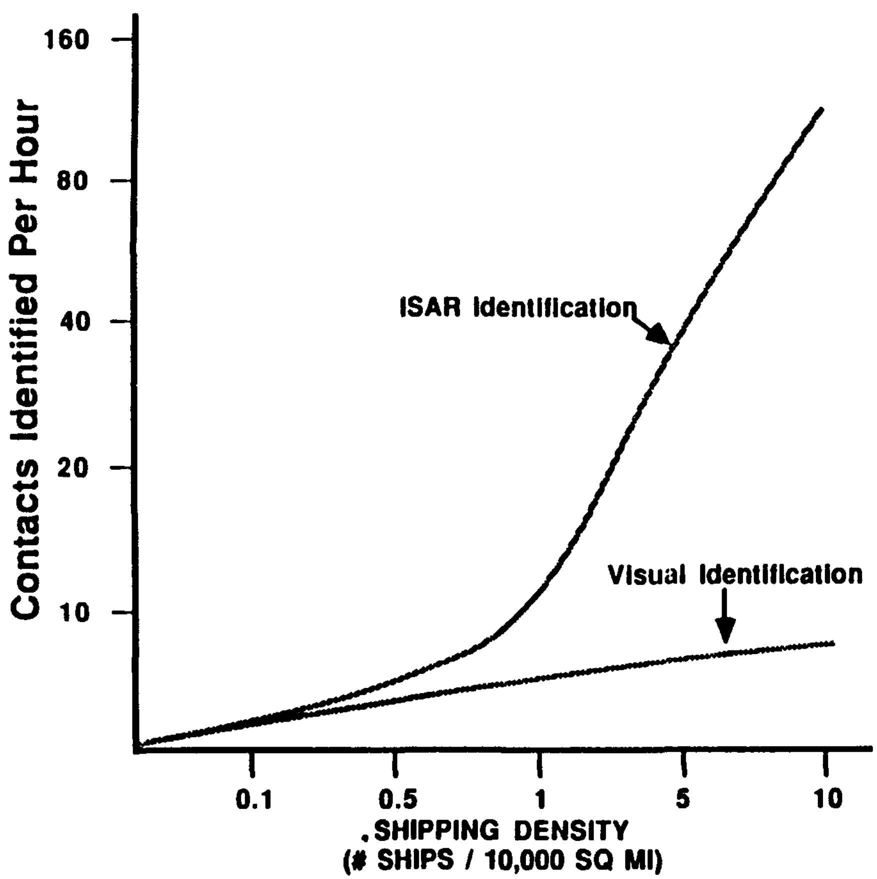
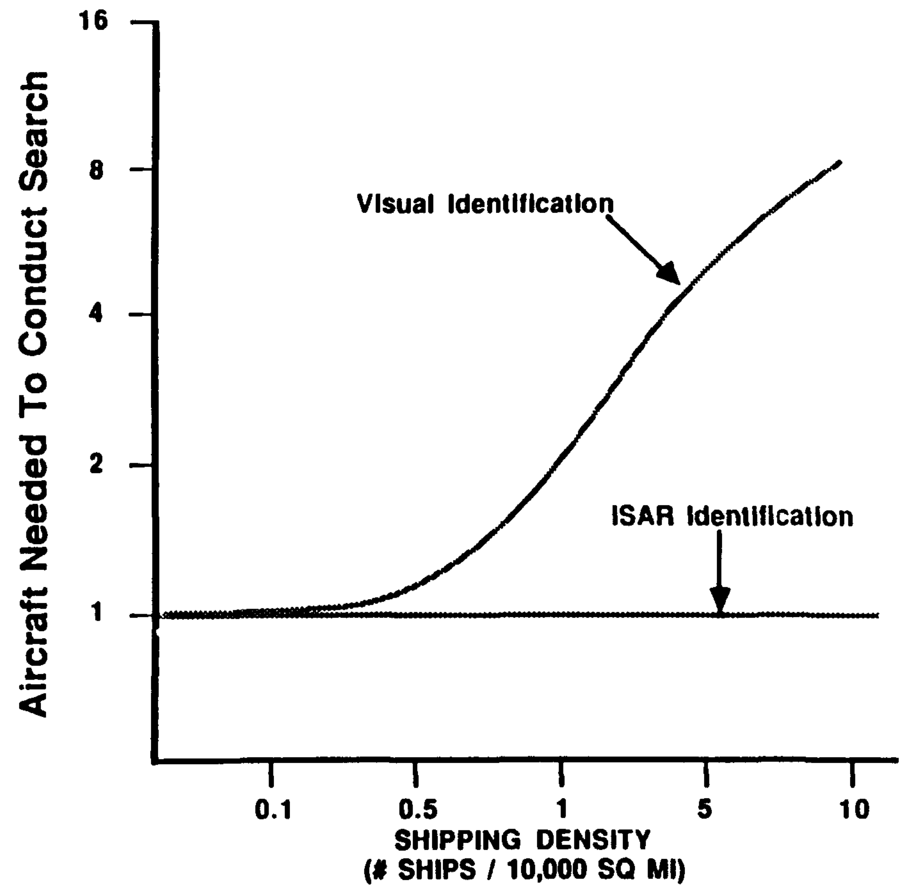
# AN/APS-137 SURFACE SEARCH RADAR
## Operational Benefits

### Search Effectiveness




### Aircraft Requirements




VJN)-89

# AN/APS-137 SURFACE SEARCH RADAR

*SIGNAL PROCESSING IMPROVEMENTS*

**RECEIVER QUANTIZER:**

CURRENT VERSION -
100 MHz ECL

UPGRADE -
200 MHz GaAs gate arrays
with CMOS memory

*RADAR SYSTEM PERFORMANCE ENHANCEMENT*

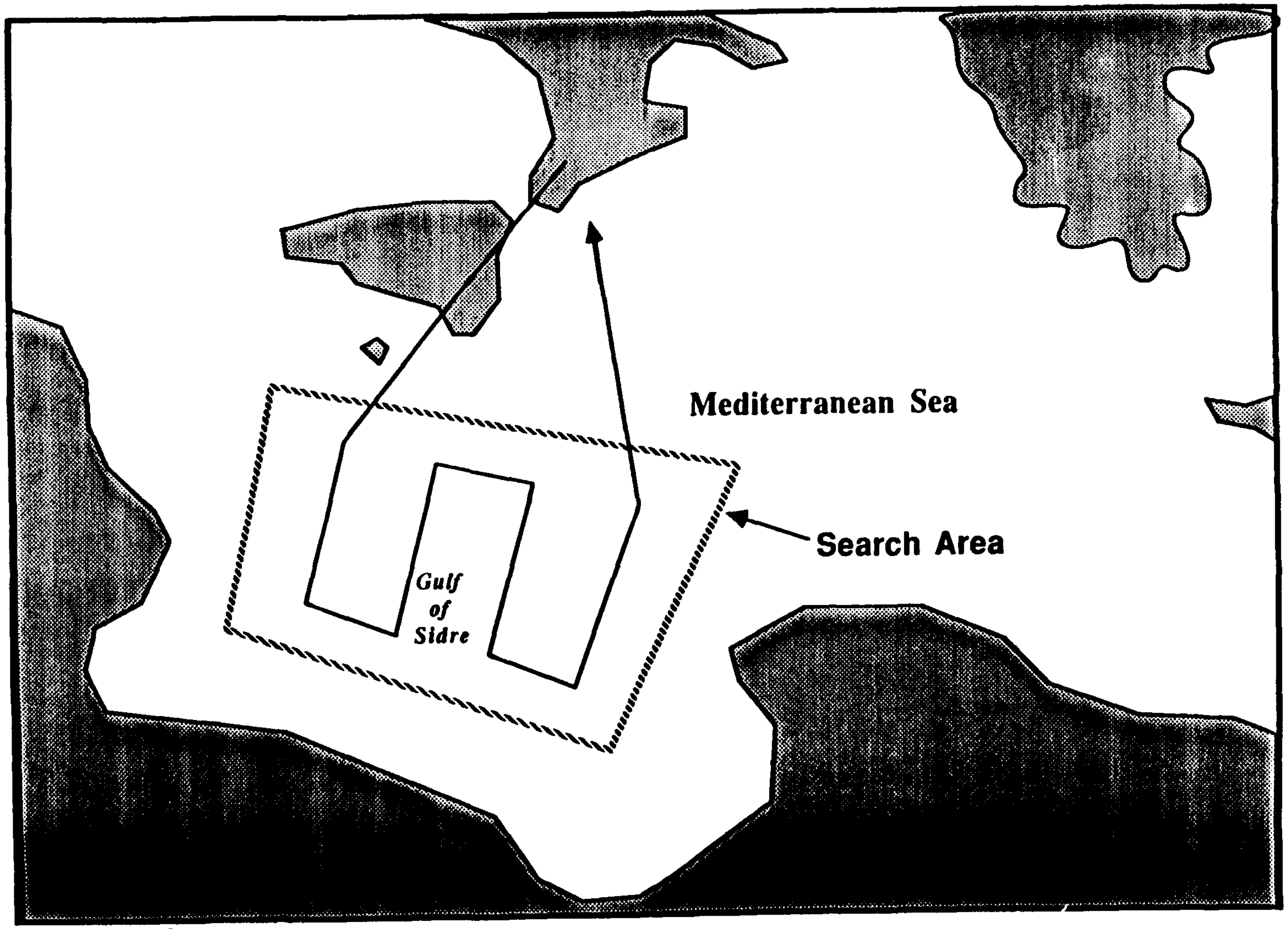
**X 2 Improvement in ISAR resolution.**

Can distinguish a missile boat from a fishing boat at beyond-visual range.

**Within available space, weight, and power**

R005(WJN)-89

# AN/APS-137 SURFACE SEARCH RADAR
## Ocean Surveillance Mission




R003(WJN)-89

# DIGITAL GaAs INSERTION SETA

## BOOZ ALLEN & HAMILTON INC.

### OBJECTIVES

- PROVIDE SYSTEMS ANALYSIS
- PROVIDE PROGRAMMATIC SUPPORT/RESEARCH
- PROVIDE COORDINATION/LIAISON

### APPROACH

- SYSTEMS OPERATIONAL RESEARCH, MODELING & SIMULATION
- DEVELOP AND MAINTAIN DATA BASES
- MAINTAIN SCHEDULES AND STATUS

### STATUS

- SYSTEMS ANALYSES COMPLETED:
  - P-3C RADAR
  - LASER RANGEFINDER
  - SLQ-32
  - LANTIRN
  - HELLFIRE
- SYSTEMS ANALYSES TO BE DONE:
  - OH-58D
  - E-2C
  - ALQ-136
  - NAVY ECM

### SCHEDULE

OH-58D - JAN 89 TO OCT 89

E-2C - APR 89 TO NOV 89

ALQ-136 - JAN 89 TO JUL 89

NAVY ECM - JUL 89 TO DEC 89

# DIGITAL GaAs INSERTION PROJECTS

## SELECTION CRITERIA

TECHNICAL FEASIBILITY

MILITARY PAYOFF

SYSTEM INSERTION PATH REALISM

# UPGRADE TO AAWWS RF-HELLFIRE MISSILE OPERATIONAL SCENARIO

- **TRADOC-Approved Scenario: HRS 3**

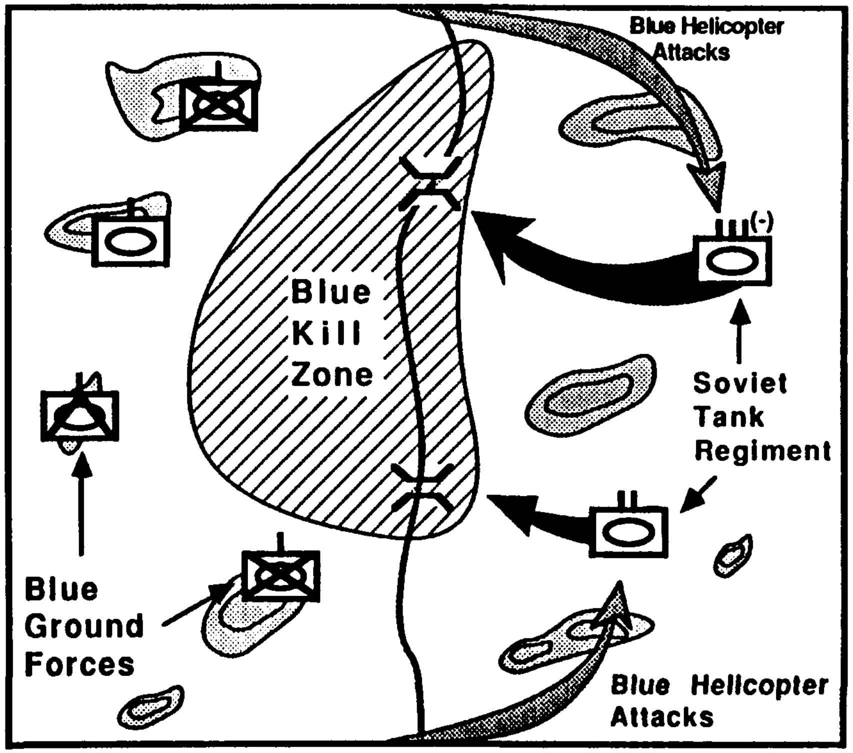
  Blue Battalion Task Force Defending
  Vs. Attack By A Red Tank Regiment.

- **Analyzed Using Army's Combined Arms Model (CARMO)**

**Force Structure**

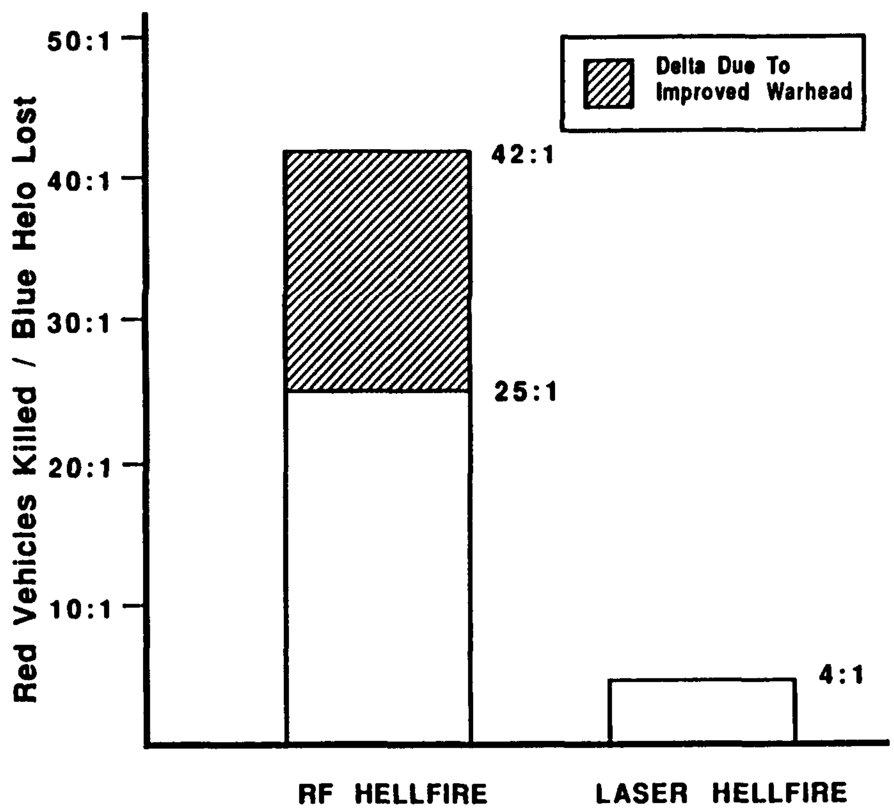
| | | | |
|---|---|---|---|
| M1A1 | 14 * | FST II | 93 * |
| IFV | 26 * | BMP | 46 * |
| ITV | 12 * | BRDM | 10 * |
| ARTY | 54 | ARTY | 208 |
| SAM | 4 * | SAM | 6 * |
| NLOS(AD) | 2 | HAVOC | 8 * |
| AH-64 | 5 * | | |
| | 117 | | 371 |
| *MANEUVER FORCES: | 61 | | 163 |

FORCE RATIO (MANEUVER) = 2.67:1

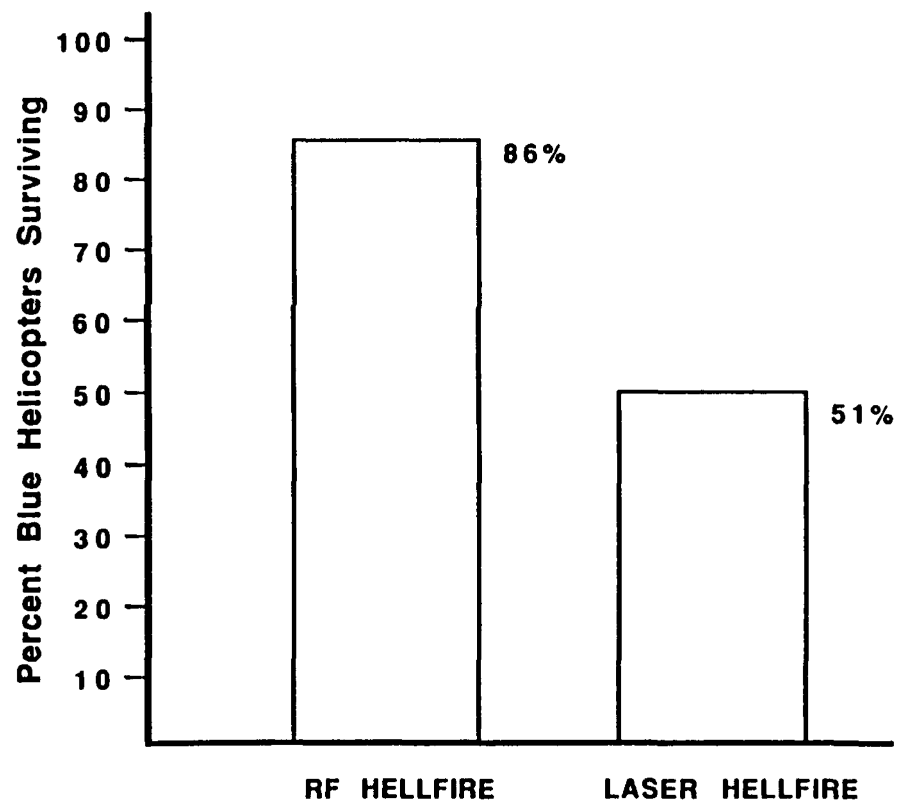


# UPGRADE TO AAWWS RF-HELLFIRE MISSILE MILITARY BENEFITS ANALYSIS

## System Exchange Ratios




## Blue Helicopter Survivability

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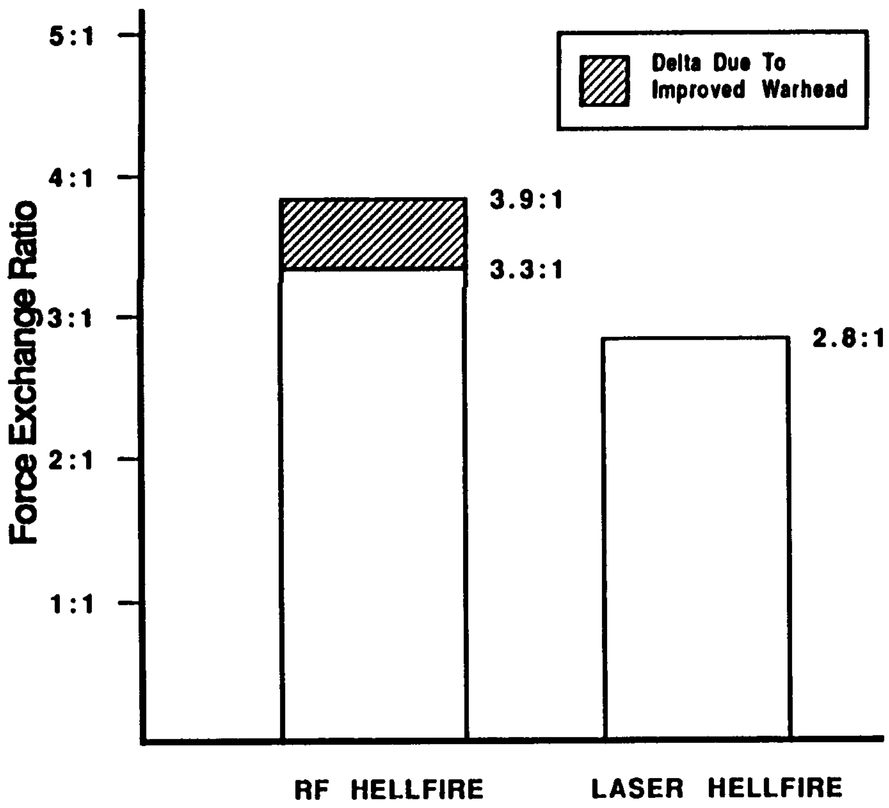
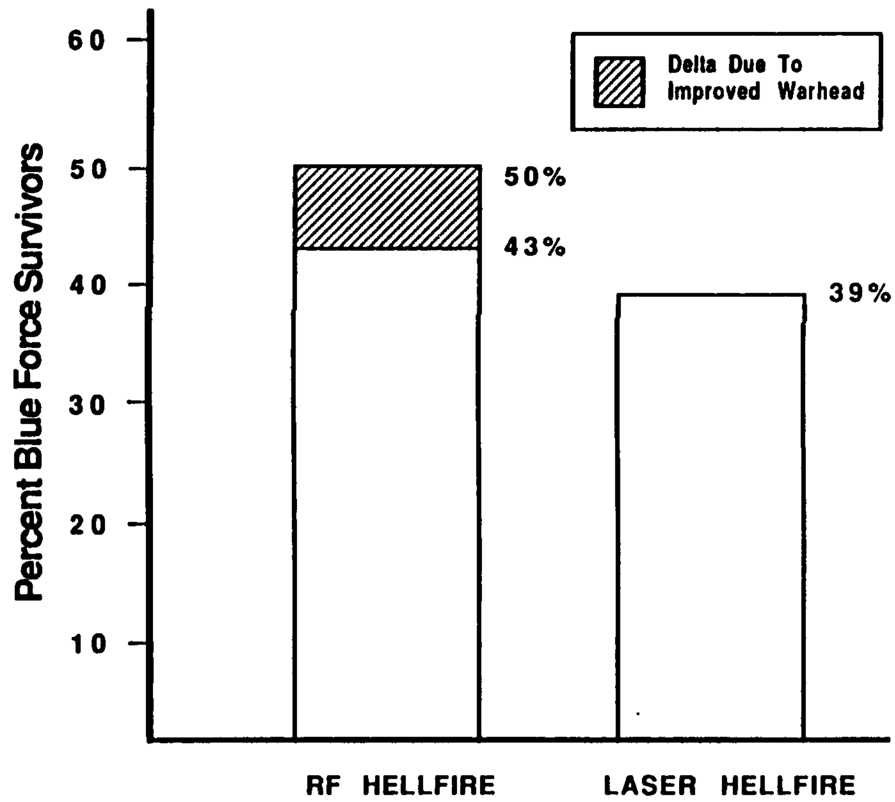
# UPGRADE TO AAWWS RF-HELLFIRE MISSILE MILITARY BENEFITS ANALYSIS

## Force Exchange Ratios




## Blue Force Survivability

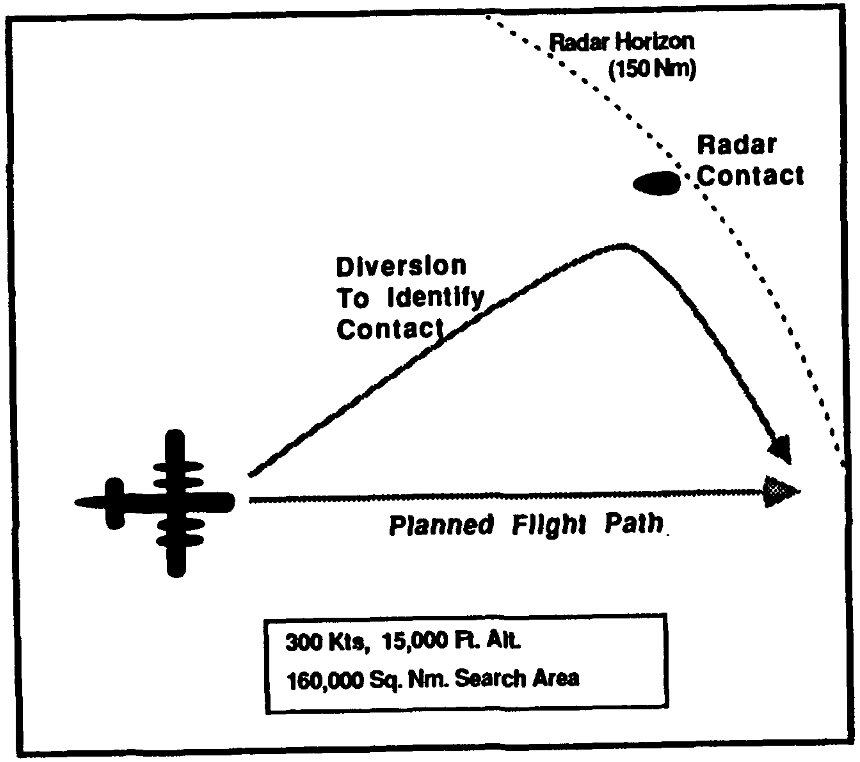


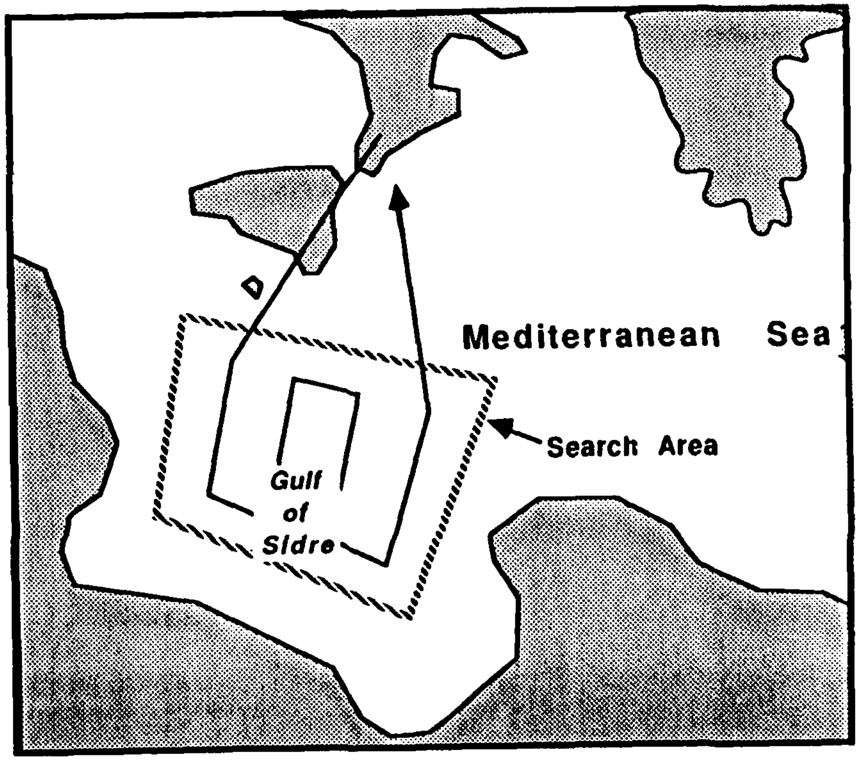
# UPGRADES TO THE AN/APS-137 AIRBORNE RADAR OPERATIONAL SCENARIO

- **Ocean Surveillance Mission:**

  Identify All Surface Ships Within Designated Search Area.

- **Improved ISAR Resolution Permits Identification Of Small Vessels Without Need For Visual Overflight.**

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# SIGNAL PROCESSOR FOR THE ADVANCED LOW FREQUENCY SONAR

## MARTIN MARIETTA

| | |
|---|---|
| Military System: | New Helicopter Dipping Sonar (ALFS).<br>Also: Sonobuoy Processor On P-3C Aircraft.<br>Torpedo Sonars.<br>Captor Mine Improvement. |
| Military Payoff: | Possible 10-13 dB Increase In Array Gain => Grea→Range<br>Reduced Wgt, Vol, And Power => In→ased Mission Time.<br>Reduced Acquisition And Life Cycle Costs. |
| Technical Approach: | Upgrade The Current Advanced Systolic Array Processor (ASAP) And Microprogrammable Controller Using High-Speed GaAs. |
| Technology Issues: | Develop And Fabricate A 1K x 8 RAM With Local Address Generation, ASAP, And Translators. |
| Programmatic Issues: | A Three Phase Insertion Schedule Proposed:<br>• Advanced Development Model - 16 Months, \$3.1 Million<br>• Engineering Prototype Dev. - 12 Months, \$2.1 Million<br>• Full Scale Engineering Dev. - 16 Months, \$1.7 Million |

090689.01

# RF HELLFIRE MISSILE UPGRADE

| | # CHIPS | # MODULES |
|---|---|---|
| CURRENT DESIGN | 250 | 4 |
| DIGITAL GaAs VERSION | 125 | 2 |

**NET 10% COST REDUCTION IN MISSILE SEEKER**

**SAVE $62 - 127M IN MISSILE PROCUREMENT**

022190.01

DARPA

# APPLICATIONS

| | |
|---|---|
| Super Computers | Major Simplifications (From Liquid Emersion To Conductive) |
| Minisupers | Significant Performance Improvement By 3-D Packaging |
| Digital RF Receivers (Wideband) | 50X Reduction In Size/Wt |
| High End Workstation (SMS) | 13X Reduction Size/Weight; 4X Increase In Performance |

**80% Of Sales Associated With Digital GaAs Are Applied To Systems For Reducing Power Dissipation**

022690.01

## Worldwide GaAs IC Market By Function

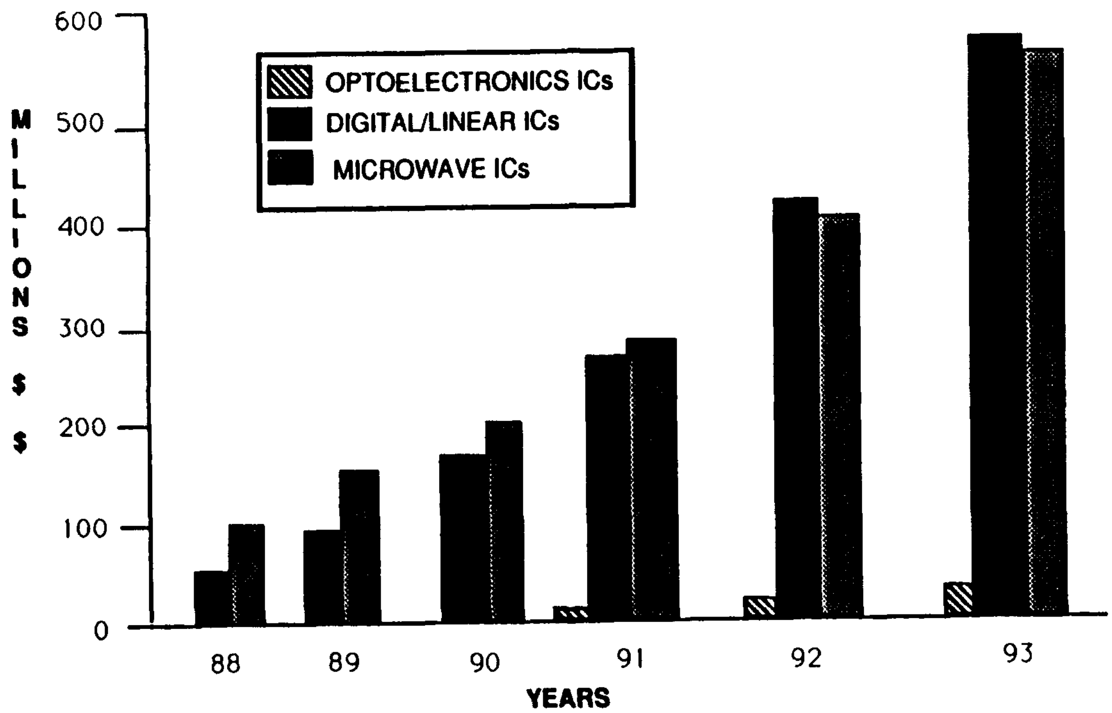



Figure 2

Source: Triquint Semiconductor

031390.01

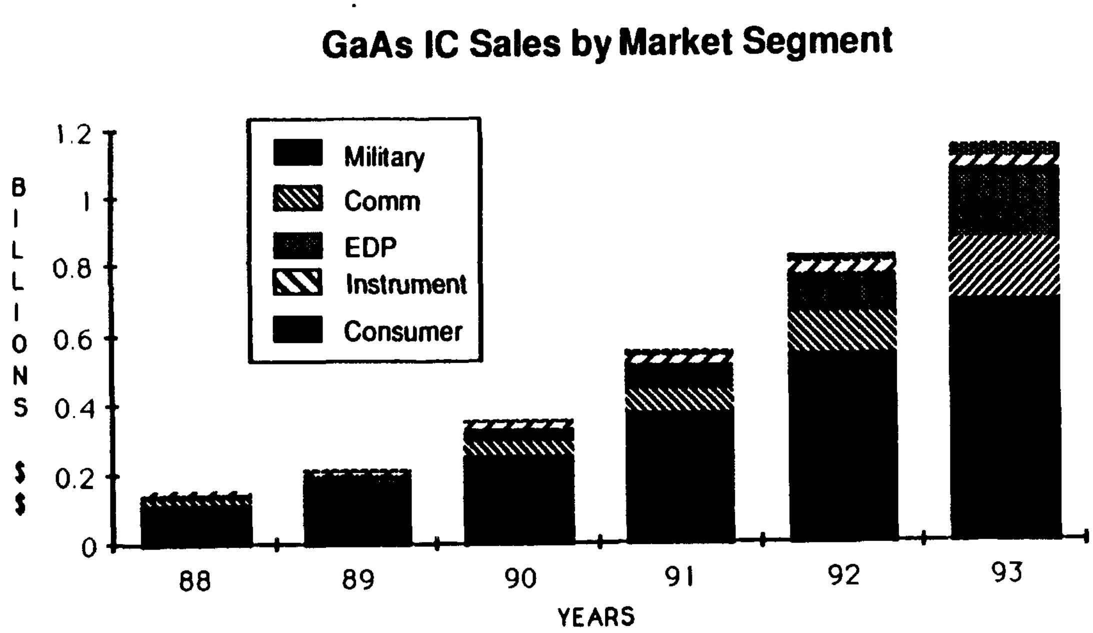


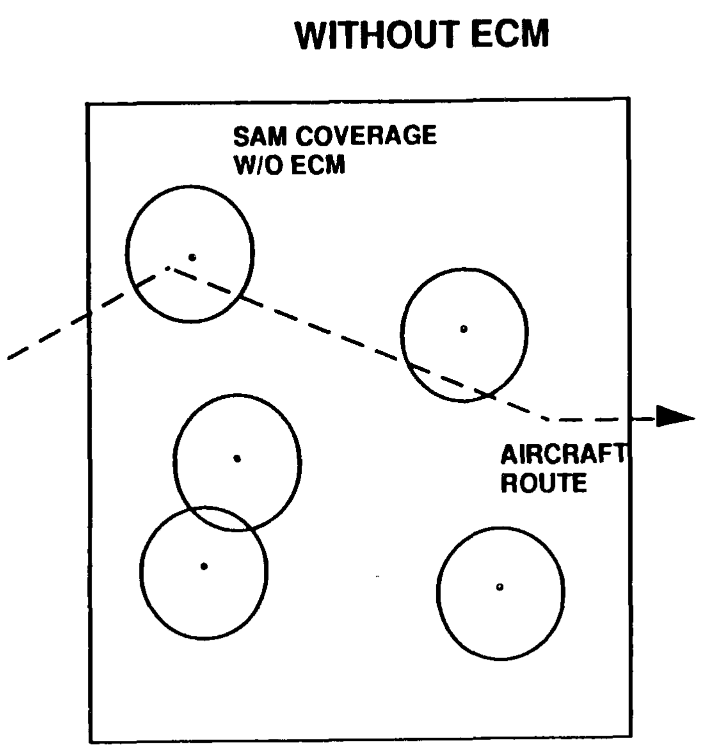

Figure 1
Source: TriQuint Semiconductor

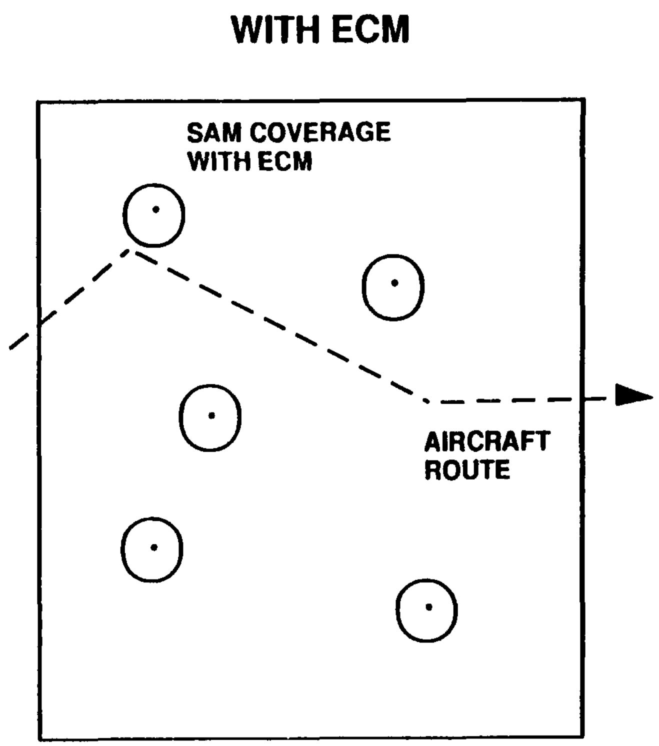
031390.02

# EFFECTIVE ECM ENHANCES AIRCRAFT PENETRATION

EVEN WITH GOOD INTELLIGENCE, NOT ALL ENEMY SAM LOCATIONS WILL BE KNOWN OR CAN BE AVOIDED

EFFECTIVE ECM PREVENTS AIRCRAFT LOSSES FROM HIDDEN/UNAVOIDABLE SAM SITES



# MILITARY BENEFITS OF DIGITAL GaAs

## ANALYSIS METHODOLOGY

SCENARIO: SINGLE AIRCRAFT PENETRATION OF ENEMY TERRITORY
- LOW ALTITUDE (<200 FT)
- HIGH SPEED (>500 KTS)

FIVE UNKNOWN SAM LOCATIONS (SOVIET SA-11)
- 1 RADAR & 4 LAUNCHERS PER SITE

BOOZ•ALLEN TACPEN MODEL:
AIRCRAFT ROUTES & SAM LOCATIONS VARIED RANDOMLY
SAM EFFECTIVE RANGE AND $P_{KILL}$ VARIED PARAMETRICALLY
MOEs: PROBABILITY OF AVOIDING ENGAGEMENT
EXPECTED NUMBER OF SAM LAUNCHES
AIRCRAFT SURVIVAL

042390.02

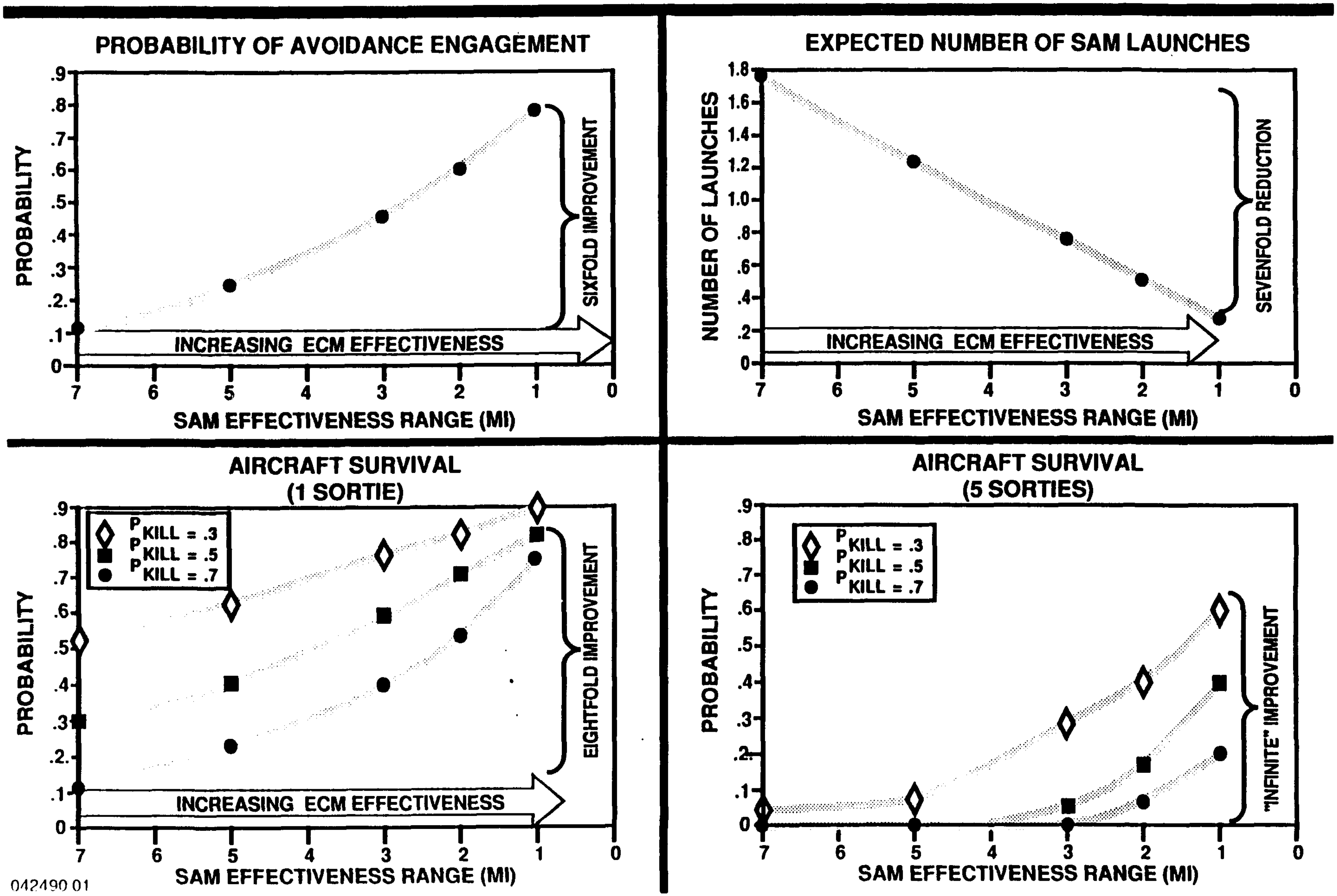
# PARAMETRIC ANALYSIS OF ECM EFFECTIVENESS -CONCLUSIONS-

- DIGITAL GaAs UPGRADES CAN ENABLE ECM SYSTEMS TO DEFEAT MODERN THREAT RADARS

- EFFECTIVE ECM CAN RESULT IN ORDER OF MAGNITUDE IMPROVEMENTS IN AIRCRAFT SINGLE-SORTIE SURVIVAL RATES
    - INCREASED PROBABILITY OF AVOIDING ENGAGEMENT
    - REDUCED NUMBER OF SAM LAUNCHES
    - SAM SYSTEM $P_{KILL/LAUNCH}$ DEGRADED

- SURVIVABILITY BENEFITS ARE MAGNIFIED ENORMOUSLY WHEN MULTIPLE SORTIES ARE CONSIDERED

# PARAMETRIC ANALYSIS OF ECM EFFECTIVENESS — RESULTS —

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# DIGITAL GALLIUM ARSENIDE MICROELECTRONICS

## UPGRADING FIELDED PLATFORMS

| *COMPANY* | *SUBSYSTEM* | *PLATFORM AND APPLICATION* | *GaAs PAYOFF* |
|---|---|---|---|
| E-SYSTEMS | DISTRIBUTED ARRAY PROCESSOR | AIR FORCE RC-135 RECONNAISSANCE AIRCRAFT | PROCESS SIX TIMES AS MANY SIMULTANEOUS SIGNALS AT 300 LBS LESS WEIGHT |
| MARTIN MARIETTA | ON BOARD PROCESSOR | SPACECRAFT | INCREASE FROM 75 MOPS TO 560 MOPS WITH NO CHANGE IN SOFTWARE |

**ALSO UPGRADING :**

| | | | |
|---|---|---|---|
| P-3C | AN/ALQ-136 JAMMER | AN/PRC-126 RADIO |
| OH-58D | AN/ALQ-126B JAMMER | LONGBOW MISSILE |

060690 02

# PRELIMINARY FINDINGS

**There Are No Applications**

**For Gallium Arsenide**

# PRELIMINARY FINDINGS

**But . . .**

**There Are Applications**

**Requiring:**

- High Speed
- Low Power
- Radiation Hardness
- Wide Thermal Range

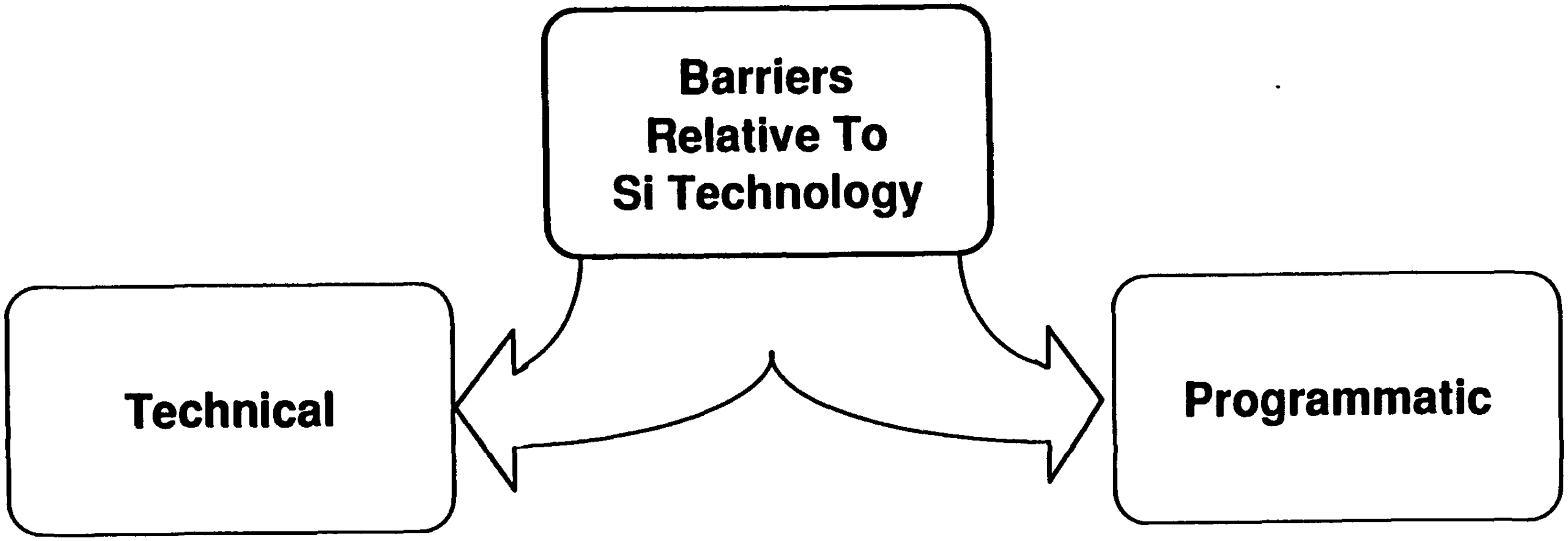
# PRELIMINARY FINDINGS

## Program Managers Will Accept Gallium Arsenide As Long As It:

- Works *And Is Needed*
- Is Available
- Doesn't Cost A Lot

**GaAs Will Be Used In Systems Only When System Designers Use It In Their Designs**

# BARRIERS TO GaAs




- Density
- Yield
- Interconnect/Packaging
- Design Techniques/Tools
- Compatibility

- Lack Of Digital GaAs "Smarts"
- Uncertain Supply
- Unproven Reliability
- Cost

# GaAs INSERTIONS
## DEMONSTRATIONS AND SCHEDULES

- E-Systems, Greenville Division (Air Force)
  - Demonstrate 100 MHz GaAs DAP to process 6X Simultaneous Signals
  - Laboratory Demonstration September 1991
- Martin Marietta Space Systems (Classified)
  - Demonstrate Greater Than 100 MHz GaAs OBP that Increases Performance From 75 to 560 MOPS
  - Breadboard Demo--December 1991, HITL Demo--September 1992
- Texas Instruments (Navy)
  - Demonstrate 200Mhz GaAs Signal Processor to Improve ISAR Resolution 2X
  - Flight Test in May 1991
- Grumman Aircraft Systems (Navy)
  - Demonstrate 200 MHz GaAs Radar Signal Processor to Achieve Detection of 37% Smaller Targets, Improve Detection Range, and Reduce False Targets
  - Feasibility Study - Apr8l 1990; Laboratory Demo--July 1992

DARPA

# DIGITAL GaAs INSERTIONS
## DEMONSTRATIONS AND SCHEDULES

*INTELLIGENCE AND SURVEILLANCE APPLICATIONS*

- **E-Systems, Greenville Division (Air Force)**
  - Demonstrate 100 MHz GaAs DAP For RC-135 to Process 6X As Many Simultaneous Signals
  - Brassboard Demo--September 1991

- **Martin Marietta Space Systems (Classified)**
  - Demonstrate Greater Than 100 MHz GaAs OBP that Increases Performance From 75 to 560 MOPS
  - Breadboard Demo--December 1991, HITL Demo--September 1992

- **Texas Instruments (Navy)**
  - Demonstrate 200 MHz GaAs Signal Processor For P-3C Radar To Improve ISAR Resolution By 2X
  - Flight Test--September 1991

- **Grumman Aircraft Systems (Navy)**
  - Demonstrate 200 MHz GaAs Radar Signal Processor For E-2C Radar To Achieve Detection of 37% Smaller Targets, Improve Detection Range, and Reduce False Targets
  - Feasibility Study--April 1990
  - No Funds For Demo

DARPA

# DIGITAL GaAs INSERTIONS
## DEMONSTRATIONS AND SCHEDULES

### *WEAPONS AND COMBAT SUPPORT APPLICATIONS*

- **McDonnell Douglas Electronics (Army)**
  - Demonstrate 100 MHz GaAs MMS System Processor For OH-58D to Increase Performance From 3.7 MOPS TO 1.4 BOPS
  - Requirements and Trade Offs Study--April 1990
  - Have Partial Funds For Brassboard Demo

- **Honeywell (Navy)**
  - GaAs Digital Map Computer To Increase Performance by 4X
  - Design Study--October 1990

- **Martin Marietta Electronics (Army)**
  - Demonstrate 240 MHz GaAs Signal Processor To Reduce Longbow Missile Seeker Costs by 10%
  - HITL Demo--September 1992

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# DIGITAL GaAs INSERTIONS
## DEMONSTRATIONS AND SCHEDULES

*ELECTRONIC WARFARE APPLICATIONS*

- **KOR Electronics (Navy)**
  - Demonstrate a 4 bit, 1 GHz GaAs DRFM To Improve Jammer Performance Against Coherent Threats At 1/2 The Cost
  - Deliver Pre-Production Model--October 1990

- **ITT Avionics (Army)**
  - Demonstrate 1 bit, 224 MHz DRFM To Provide 8X Improvement In Threat Handling Capability
  - Brassboard Lab Demo--February 1991

- **Sanders (Navy)**
  - Demonstrate 1 GHz GaAs IF Processor To Provide Jamming Capability For New Class of Threats
  - Brassboard Lab Demo--August 1992

*COMMUNICATIONS APPLICATION*

- **E-Systems ECI Division (Army)**
  - Demonstrate 400 MHz GaAs Modem/Demux and A/D Converters for PRC-126 Radio To Provide Multi-mode, Multi-band, Spread Spectrum Capabilities For SINCGARS Interoperability
  - Brassboard Lab Demo--March 1992

DARPA

# Gallium Arsenide Work at Vitesse

MTO

| Company | System | Chip | Process | Gates | Tape Out Date | $ Value |
|---|---|---|---|---|---|---|
| Martin Marietta-Denver | OBP | MPY | HGaAs I | 9.0 K | Nov 90 | $211 K |
| | | GALU | HGaAs I | 24.5 K | Feb 91 | $197 K |
| | | IPR | HGaAs I | 9.0 K | Apr 91 | $187 K |
| | | DMC | HGaAs I | 5.0 K | Apr 91 | $168 K |
| | | TIC | HGaAs I | 5.0 K | May 91 | $187 K |
| | | COMM1 | HGaAs I | 5.0 K | Jul 91 | $168 K |
| | | MCS | HGaAs I | 12.0 K | Jun 91 | $187 K |
| Aerospace Corp. | Process & Reliability | | HGaAs II | 6.0 K | Sep 91 | $ 79 K |
| KOR Electronics | DRFM | DMA | HGaAs III | 30.0 K | Aug 91 | $ 85 K |
| ITT Avionics | ATRJ | DRFM | HGaAs II | 12.5 K | have parts | $100 K |
| | | FSIC | HGaAs II | 0.4 K | have parts | $ 70 K |

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# Gallium Arsenide Work at Vitesse (Continued)

| Company | System | Chip | Process | Gates | Tape Out Date | $ Value |
|---|---|---|---|---|---|---|
| Lockheed Sanders | ALQ-126B | DIFM-1 | E/D MESFET | 4.6 K | Aug 91 | $193 K |
| | | DIFM-1 | E/D MESFET | 4.3 K | May 91 | $250 K |
| | | SC-1 | E/D MESFET | 3.0 K | Aug 91 | $145 K |
| | | DSC-3 | E/D MESFET | 3.8 K | Sep 91 | $250 K |
| McDonnell Douglas | OH-58D MMS | DSP | HGaAs III | 50.0 K | May 92 | $600 K |
| Martin Marietta-Orlando | RF Hellfire | ACM | HGaAs III | 35.0 K | Nov 91 | $869 K |
| | | VPM | HGaAs III | 35.0 K | Dec 91 | |
| E-Systems | RC-135 DAP | PR(EZ9) | HGaAs II | 14.7 K | have parts | $32 K/unit, 25 units = $800 K |
| | | MC(EX10) | HGaAs III | 55-60 K | Nov/Dec 91 | |
| | | | | | Total: | $4,746 K |

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# DIGITAL GaAs UPGRADE FOR OH-58D MMS PROCESSOR

## COST BENEFITS

- Two Times Improvement in Survivability
- Four Times Improvement In Effectiveness
  - Fewer Platforms Required
  - Elimination of Some Existing Platforms (AH-1)
- Permits Delay of LH
- Reduced Board Count (25 → 6) Results In $45M Savings in Logistics LCC

# DIGITAL GaAs UPGRADE FOR SPACECRAFT ONBOARD PROCESSOR

- Removes Current Processing Bottlenecks (75 MOPS → 560 MOPS)
- Uses Current Software, Extends Useful Lifetime (Major Savings)
- Upgraded Box Will Cost 10% of Current Box
- Greatly Improved Reliability
  - -Reduced Board Count (14 → 1)
  - -Reduced Chip Count
  - -Greatly Reduced Board and Chip Interconnects
  - -Triple Redundancy
- Total Radiation Dose Hardness Improved by 4 Orders of Magnitude

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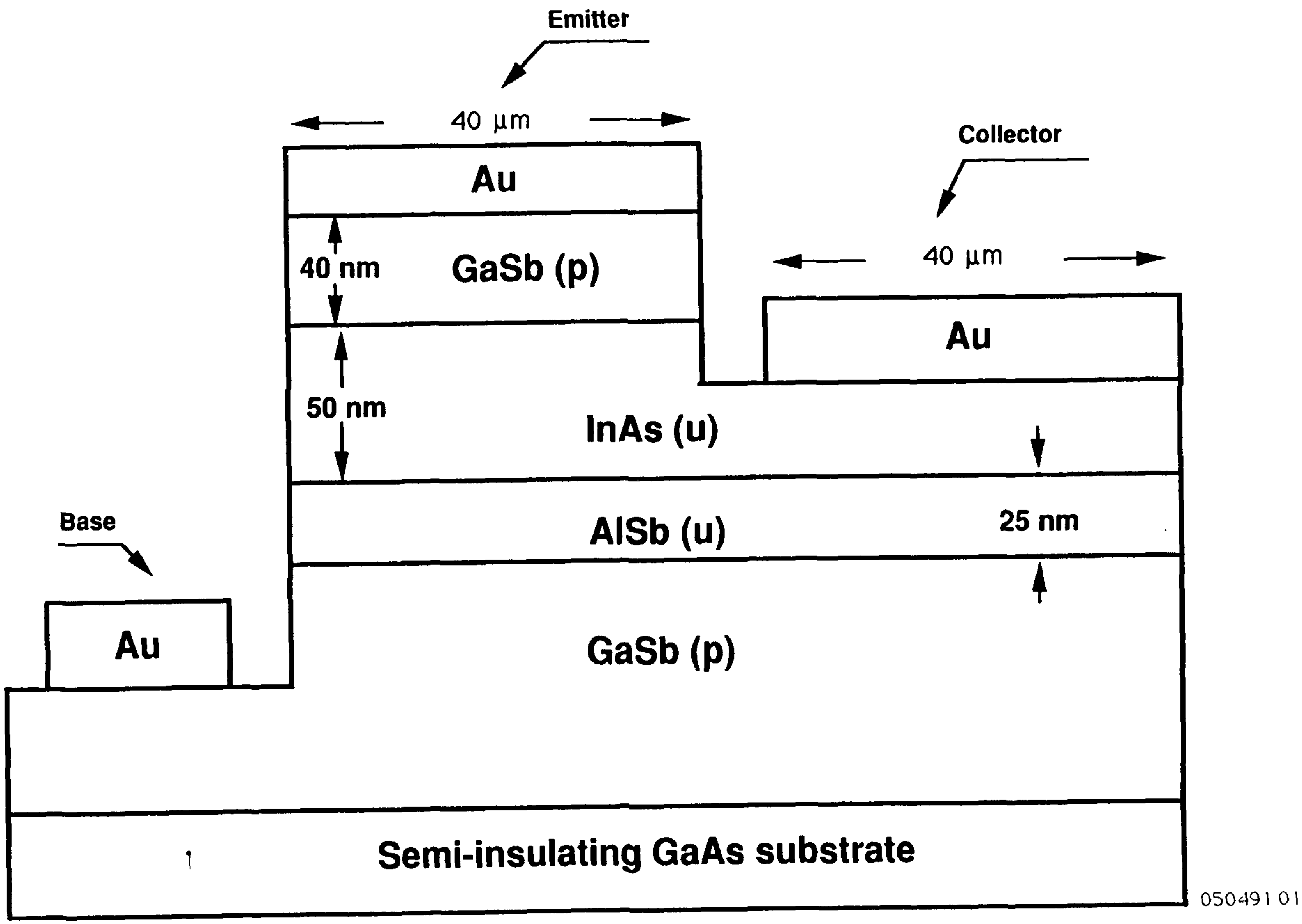
# STARK EFFECT TRANSISTOR



# COMPONENT COST VS. SUBSYSTEM COST

## DLQ Target Drone Electronic Countermeasures System

| | Silicon | GaAs |
|---|---|---|
| Gate Array | \$250 | \$750 |
| Digital RF Memory Subsystem | \$150K | \$80K |

# TECHNOLOGY APPLICATIONS

- Digital Gallium Arsenide (GaAs) Insertion Projects Program
  - -- $56M DARPA Program To Accelerate Use of Digital GaAs ICs
  - -- Booz•Allen Provides SETA Support to DARPA Program Manager
    - -- System Ops Analysis, Cost/Benefit Analysis, Prog/Admin Support

- High-Density, High-Speed Electronic Packaging (Multichip Modules-MCM)
  - -- $37M DARPA Program to Develop MCM Foundry Capability
  - -- Booz•Allen Providing SETA Support

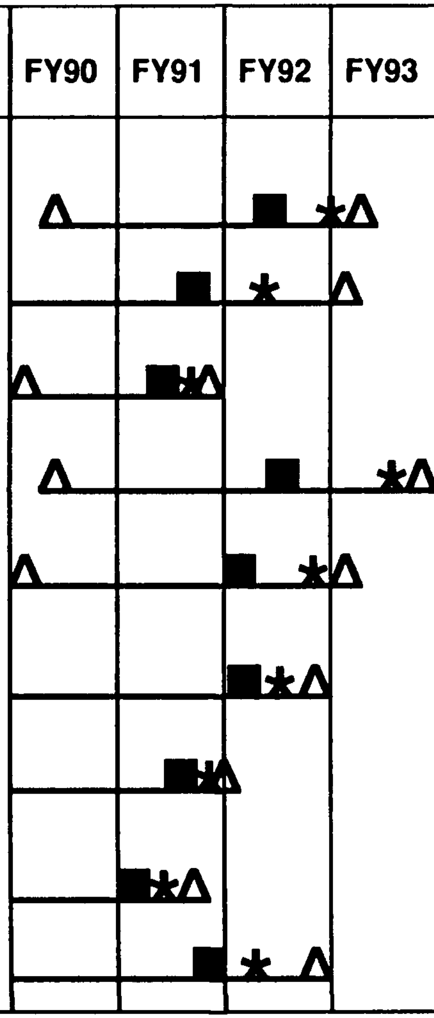
- High Temperature Superconductivity Program
  - -- $30M Per Year DARPA Program To Develop HTS Technology
  - -- Booz•Allen Providing Technical Assessments of Pay-offs

- Man-made Diamond Technology Program
  - -- DARPA Program To Develop Diamond Substrates For Electronics
  - -- Booz•Allen Will Provide Applications Pay-off Analyses

- Optical Processing Demonstration and Insertion Program
  - -- Proposed DARPA Program To Demonstrate Maturity of Optoelectronics
  - -- Booz•Allen Providing Support In Program Development and Pay-offs

# DIGITAL GaAs INSERTIONS

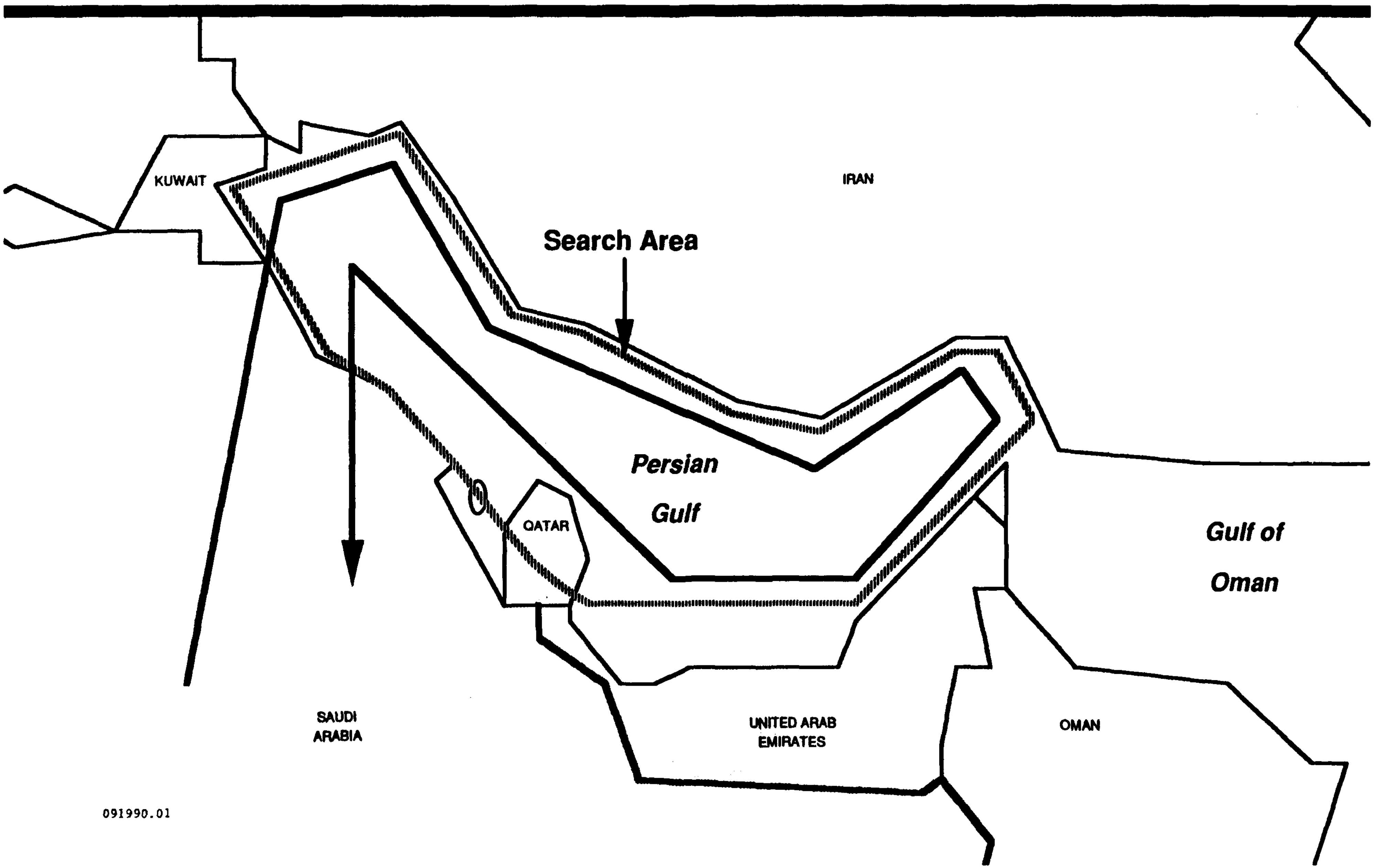
| INSERTION / PLATFORM | | NEXT STEP |
|---|---|---|
| E-SYSTEMS | RC-135 | • FSED FOLLOW-ONS PRODUCTION |
| MARTIN MARIETTA | OBP | |
| TEXAS INSTRUMENTS | P-3 | |
| MDESC | OH-58D | • ENHANCED TECH BASE FUTURE INSERTIONS |
| MARTIN MARIETTA | LONGBOW | |
| LOCKHEED SANDERS | ALQ-126B | |
| E-SYSTEMS | PRC-126 | |
| ITT | ALQ-136 | |
| KOR ELECTRONICS | ULQ-21 | |




* INSERTION DEMONSTRATION

■ INSERTION IC's COMPLETE

## AN/APS-137 SURFACE SEARCH RADAR
### Notional Ocean Surveillance Mission

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DARPA

# DIGITAL GaAs INSERTION PROJECTS

## EMERGING TRENDS

- TODAY'S GaAs LOGIC CIRCUITS FIND WIDE APPLICATION
  - MANY COMPETING SYSTEMS REQUIRE ECL SPEED BUT CANNOT AFFORD THE POWER, SIZE OR WEIGHT
- TODAY'S GaAs MEMORIES ARE TOO LIMITED IN DENSITY
  - ONLY 2 OF 9 UPGRADE PROJECTS WILL USE GaAs MEMORY

# DARPA DIGITAL GaAs PROGRAM

# AN/ALQ-126B

FEBRUARY 21, 1992

# DARPA DIGITAL GaAs PROGRAM
# AN/ALQ-126B

- TECHNOLOGY DEVELOPMENT PROGRAM SPONSORED BY NAVAIR TO DEMONSTRATE AND PROTOTYPE ELECTRONIC FUNCTIONS IN DIGITAL GaAs TECHNOLOGY TO SIGNIFICANTLY ENHANCE CAPABILITY OF THE PRESENTLY FIELDED SYSTEM
  - DEVELOP A COST-EFFECTIVE APPROACH TO PROVIDE ECM CAPABILITY AGAINST NEW CLASS EMITTERS
  - ACCOMMODATE MODIFICATIONS WITHIN VOLUME OF CURRENT SYSTEM FACILITATED BY DIGITAL GaAs MODULES

# PROGRAM GOALS FOR ALQ-126B DGAS

- PROVIDE AFFORDABLE ECM UPDATE FOR AIRCRAFT WHICH WILL CARRY THE ALQ-126B
- IMPLEMENT IMPROVED CAPABILITY AGAINST
  - CW/PD THREATS
  - MONOPULSE
  - MULTIPLE SIGNAL ENVIRONMENT
- MINIMIZE AIRCRAFT GROUP A CHANGES

# ENHANCED ALQ-126B CONCEPT

## ENHANCED ALQ-126B CONCEPT

- MODIFY UPPER DECK WITH DIGITAL GaAs MODULES
  - INCORPORATES PD/CW PROCESSING CAPABILITY
  - IMPROVED MULTIPLE SIGNAL HANDLING

- NO CHANGE TO LOWER (TRANSMITTER) DECK
- MINIMAL CHANGE TO GROUP A RF XMISSION LINES
- INTERFACE ALQ-126B WITH IDAP PROGRAM VIA RF LINK TO OFF-BOARD SYSTEM
- TRANSMIT ON-BOARD/OFF-BOARD VS. PULSE THREATS
- TRANSMIT "SMART" OFF-BOARD VS. CW/PD THREATS

# ALQ-126B ENHANCED CAPABILITIES

TACTICAL AIRCRAFT JAMMER REQUIREMENTS FOR 1990's

- NEWER THREATS HAVE MONOPULSE CAPABILITY
- OLDER THREATS REMAIN IN INVENTORY THRU 2000
- TACTICAL AIRCRAFT NEED ECM UPGRADES TO COUNTER MONOPULSE
- MANY MONOPULSE ECM TECHNIQUES ARE AVAILABLE
  OFF-BOARD DECOY IS MOST AFFORDABLE AT LOWEST RISK
- OFF-BOARD DECOYS WON'T COUNTER OLDER THREATS AND FACE INTEGRATION PROBLEMS WITH ON-BOARD CW/PD JAMMERS

- THEREFORE -

A COMBINATION OF ON-BOARD PULSE JAMMING FOR OLDER THREATS AND OFF-BOARD JAMMING FOR NEWER THREATS IS AN EXCELLENT SOLUTION

DARPA

# POTENTIAL PLATFORMS WITH ALQ-126B & TOWED TRANSMITTER

MTO

| | | NO. OF A/C | STATUS |
|---|---|---|---|
| USN | | | |
| | F-18A/B | 400 | • ALL AIRCRAFT HAVE ALQ-126B |
| | *A-6E(2 PER AC) | 200 (400) | |
| | F-14A/A+ | 200 | |
| USMC | AV-8B W/ALQ-164 | 70 | |
| INTERNATIONAL | F-18 CAN, AUS, SPAIN | 200 | |
| | TOTAL | 1270 | CANDIDATES FOR ALQ-126B DGAS/TT |

* (2) ALQ-126B(s) PER AIRCRAFT - UTILIZE EXISTING LOWER DECKS
ALE-50 INSTALL ALREADY PLANNED FOR PLATFORM

DARPA MTO

# TASKS TO ENHANCE ALQ-126B

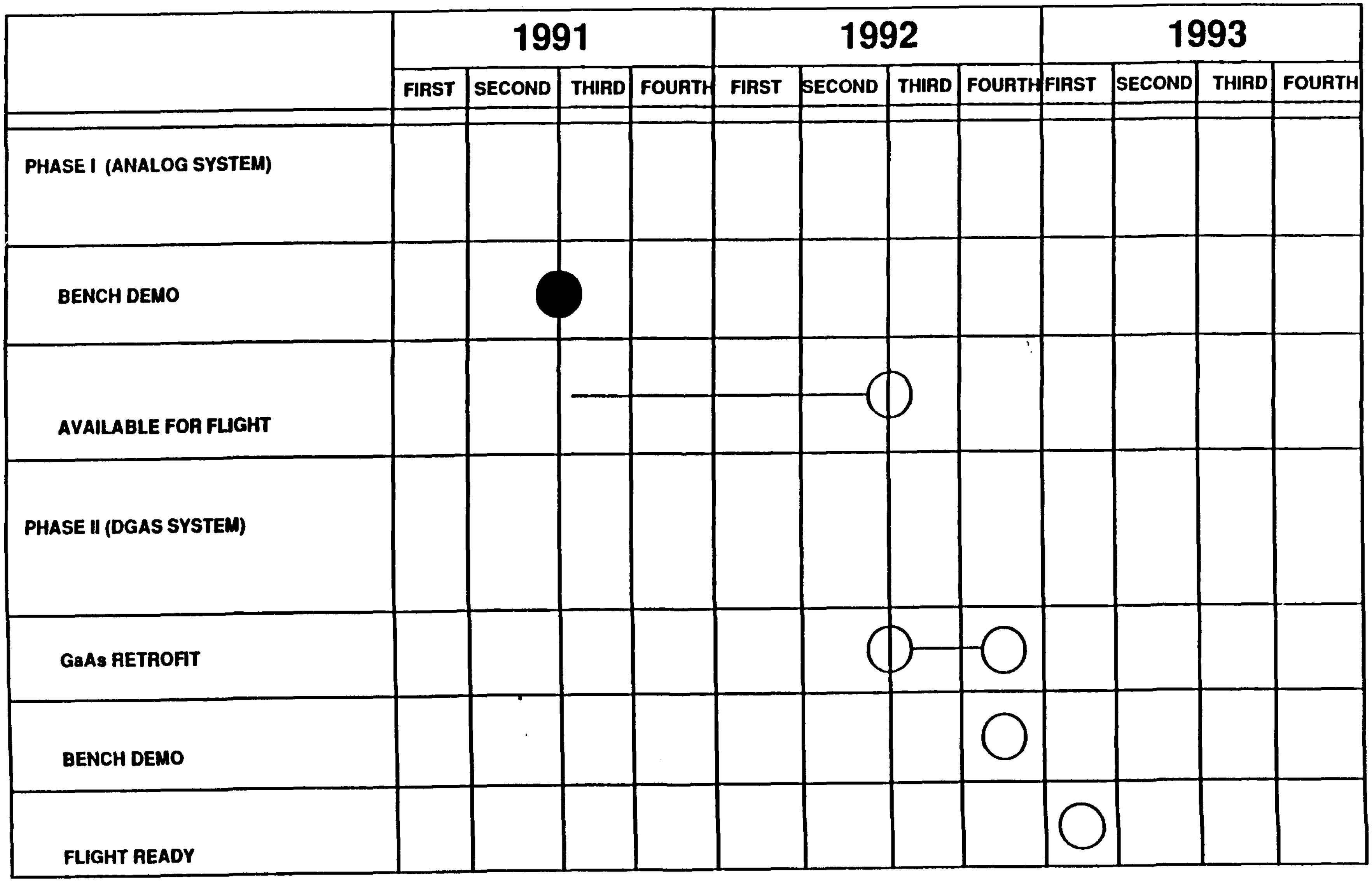
- DARPA CONTRACT
  - DEVELOP CHIPS AND MODULES COMPATIBLE WITH ALQ-126B
    4 CHIPS 5 MODULES TOTAL - 2 GaAs MODULES
    BENCH DEMONSTRATION 4TH QUARTER '92

- LOCKHEED SANDERS ALQ-126B IR&D
  - TWO PHASED APPROACH FOR EARLIER IMPLEMENTATION
  - DEMONSTRATE SYSTEM LEVEL CAPABILITY
    PHASE I - ANALOG DIFM & DRFM SUCCESSFULLY BENCH TESTED SUMMER '91
    - AVAILABLE FOR FLIGHT TEST UNTIL GaAs RETROFIT IS INITIATED (JULY)

    PHASE II - RETROFIT SYSTEM WITH DARPA GaAs DEVELOPMENTS
    - READY FOR FLIGHT 1ST QUARTER '93

- NRL TOWED TRANSMITTER DEVELOPMENT
  - DEVELOPS DECOY AND COMMUNICATIONS LINKS
  - INTERFACE WITH ALQ-126B
  - FLIGHT TEST TO DEMONSTRATE COMMUNICATIONS LINK

# SCHEDULE



1991
1992
1993
FIRST
SECOND
THIRD
FOURTH
FIRST
SECOND
THIRD
FOURTH
FIRST
SECOND
THIRD
FOURTH
PHASE I (ANALOG SYSTEM)
BENCH DEMO
AVAILABLE FOR FLIGHT
PHASE II (DGAS SYSTEM)
GaAs RETROFIT
BENCH DEMO
FLIGHT READY

DARPA MTO

# ALQ-126B CAPABILITIES ENHANCEMENT

- COMMITMENT TO ENHANCEMENT OF THE ALQ-126B
  - DARPA CONTRACT FOR GaAs INSERTION — $3.2M
  - CONTRACTOR IRAD FOR SYSTEMS MODS — 2.0
  - $5.2M

- INTENT IS TO FIELD DARPA TECHNOLOGY DEVELOPMENTS
  - UPGRADES ARE SOLD THROUGH DEMONSTRATION
  - ALQ-126B DGAS NEEDS NAVAIR FLIGHT TEST INTEREST

# ENHANCED ALQ-126B

## SUMMARY

- EXISTING ON-BOARD ECM SYSTEMS REQUIRE ENHANCEMENT
  - ENHANCED ALQ-126B IS COST EFFECTIVE SOLUTION
- ENHANCED ALQ-126B + OFF-BOARD + RF LINK PROVIDE A ROBUST SUITE
  - PREFERRED MONOPULSE SOLUTION
  - RAIL KEEPING TECHNIQUES
  - ROBUST MISSILE END GAME JAMMING
- ENHANCED ALQ-126B REQUIRES MINIMAL A KIT MODIFICATIONS
- OFF-BOARD PROGRAM PROCEEDING INDEPENDENT OF ALQ-126B

# RECOMMENDATION

SUPPORT THE AN/ALQ-126B DGAS EFFORT

- NRL COORDINATION FOR SYSTEM/DECOY INTERFACE
- BENCH TEST RF/FIBER OPTIC LINK
- IDENTIFY TIME FRAME/PLATFORM/RESOURCES FOR FLIGHT TEST

PROVIDES COST EFFECTIVE SOLUTION TO PROVEN FIELDED SYSTEM

# APPENDIX 2

## Trip reports

Dan Butler, program mananger for Booz•Allen, traveled extensively to contractor preliminary design reviews, in-oprogress reviews as well as technical workshops and conferences. Data collected at these meetings was reduced and communicated to DARPA MTO staff, frequently by means of a trip report. Samples of this work are attached.

BOOZ•ALLEN & HAMILTON Inc.
Advanced Technology Applications Practice

*Memorandum*

Ballston
October 11, 1991

To: Zachary J. Lemnios

From: Dan Butler AL for DD

Subject: Trip Report, Martin Marietta Electronic Systems-Orlando-Digital GaAs Processor-In-Progress Design Review

On October 1-2, 1991, I attended the subject IPR at the Martin Marietta facility in Orlando, Florida. Many serious problems were noted during this review: the most serious will be recorded here:

(1) Original design goals of processor clock speed of 240 MHz and throughput of 2.4 GFLOPS have been scaled back to 160 MHz and approximately 600 MFLOPS. This change was due to the inefficiencies associated with using Vitesse's GaAs III sea of gates chip.

(2) The GaAs processor is now estimated to dissipate 90 Watts maximum power. This is far above the current silicon system of 52.5 Watts. To reduce the power consumption to 52.5 Watts will require a complete redesign of the chip set.

(3) Clock distribution and board layout are potential trouble spots. Martin Marietta plans to use the Mayo-designed clock distribution chip only for the breadboard. Apparently, Martin Marietta has decided to use multichip module packaging in the brassboard configuration with the hope that asynchronous clocking will work. Clocking will be done somehow by tapping into the exciter (1.44 GHz clock). Using standard packaging, 344-pin packages required. I do not believe that a clock distribution chip can be fitted on the board.

(4) The design to unit production cost (DTUPC) is now estimated to be $4,040 per missile. This DTUPC assumes using multichip module packaging; standard packaging will lower cost savings to approximately $3,000 per missile. Vitesse would only supply prices for 1-3,000 chips (packaged) and Martin needs price for 40,000 chips so they can be used for the DTUPC estimate known prices for buying equivalent number of R3000 chips.

(5) Current design for RF Hellfire uses a custom designed power supply providing +5V, -5.2V, -2V, and +3.3V. GaAs chips require +2V, meaning separate 2V power supply will have to be incorporated; redesign of custom power supply will be too expensive. Where to locate (packaging) this 2V power supply is an unresolved problem.

(6) Schedule has slipped three months.

All of the above problems are potential show stoppers, but of particular concern are power dissipation and clocking. Both will require major redesign to solve the problems. The following action items were generated:

(1) Martin Marietta to redo the DTUPC estimate using standard packaging vice MCMs; to be presented at October 11, 1991, meeting at MICOM.

(2) Martin Marietta to develop options to correct power dissipation problem: to be presented at a meeting shortly after November 1, 1991, at a location to be determined.

(3) MICOM Engineers (Jerry Adams, Ray Bates, and Dave Lawson) to discuss implications of the IPR and present to DARPA prior to October 11th meeting. Dave Lawson has agreed to travel to Washington, DC, and met with Zach and Arati.

Options available to DARPA:

(1) Continue effort as is:
  a. Benefit -- no cost impact. Will demonstrate functionality of GaAs processor.
  b. Disadvantage -- will not meet MICOM requirements. Will require MICOM to pay for redesign to meet power budget.
  c. Possibilities -- if cost benefits are still there, at end of DARPA program cost estimates should be firmer, MICOM may proceed.

(2) Terminate the effort now (after November 1 meeting):
  a. Benefit -- remaining $3M can be redirected to other projects.
  b. Disadvantage -- will have gotten nothing for initial $5.4M investment.
  c. Possibilities -- MICOM still wants lower cost processor, might be willing to cost share redesign to "save" project.

(3) Redirect remaining $3M to redesign chip set:
  a. Benefit -- chip set will meet specifications.
  b. Disadvantage -- activities necessary to demonstrate prototypes will be unfunded; will extend schedule by at least 12 months; cost impact approximately $3M.

It is probable that Martin Marietta will, by November 1, develop additional options. No decisions need be made until after January 1, 1992, as Martin Marietta's current funding will last until April 1992.

One positive action was noted--two new engineers have been assigned full-time to the project: John Huhns, electronic systems engineer, and Matt Amatangelo, IC designer. Had these two engineers been on the project from the beginning, many problems might have been avoided. In a private, one-on-one conversation with Marty Tanenhaus' boss, Dr. Keith Huddleston, I suggested that Keith had to become more personally involved in the project. Despite all the technical problems noted above, I believe the biggest problem facing the future of this project is engineering management. Without changes at the top, I do not believe this project will succeed.

Attachments: Attendence List
IPR Briefing
GaAs Vector Processor IPR (Zoran)
Martin Marietta/Mayo Clock Distribution Circuit Design Briefing (B. Randall)
Schedule

cc: Arati Prabhakar

BOOZ•ALLEN & HAMILTON Inc.
Advanced Technology Applications Practice

*Memorandum*

Ballston
October 11, 1991

To: Zachary J. Lemnios

From: Dan Butler

Subject: Trip Report, E-Systems-Greenville-DAP

On October 4, 1991, I met with Jim Worrell, Det. 2; Mike Smith, E-Systems Program Manager; John Hodapp, E-Systems Systems Engineer; and Gary Hyatt, E-Systems Marketing. E-Systems presented a technical and financial update on their GaAs insertion project.

Like Martin Marietta, E-Systems has been impacted by the Vitesse decision not to support HGaAs III standard cell. E-Systems reported that Vitesse 344-pin package will accept only 20 watts; therefore, they have been forced to go to 456-pin bump grid array package. This will add considerable risk to the project.

The PDR for the MCC chip is now scheduled for the first week of November, 1991. Any slip in this review will result in a one-for-one slip in the overall schedule.

A major problem noted in this update is that the cost overrun on the project is now estimated to be $1M. Jim Worrell indicated Det. 2 had no funding to cover the overrun. Existing funding will run out in April 1992 (project is fully funded by DARPA already), which means E-Systems will have chips in hand but no means to mount them in prototype boards, assemble, or test the system.

Equally distrubing as the cost overrun was the final E-Systems presentation comparing the DAP510 to both the GaAs DAP and a new CMOS development. Apparently, this new CMOS machine (designated DUAL 530C ATR) will, in E-Systems' estimation, out perform the GaAs DAP. Therefore, E-Systems recommends that DARPA fund the overrun of $1M to finish the demonstration of the GaAs DAP and then invest $1.6M to upgrade the GaAs DAP so it will outperform the 530C ATR.

Since this project is already fully funded, the only options are to either accept whatever comes out of the project at the end of current funding (far short of program objectives), or to find an additional $1M. Jim Worrell suggested that if DARPA could find some FY93 funds, he might be able to find some FY92 funding to keep the project going until FY93. Worrell said he would contact Zack to discuss the issue.

The $1M estimate to complete the current program is based on the successful completion of the MCC chip design and fabrication. This estimate could go much higher if additional problems are discovered or the schedule slips further. Based on past experience with E-Systems and Vitesse on this project and Vitesse on other projects, the probability of meeting schedule is low.

E-System's motivation in proposing to DARPA at this time an upgrade to the yet-to-be completed GaAs DAP is unclear. It seems to me that what E-Sytems is saying is that only with further investment of $2.65M or more will DARPA be able to produce a processor that will be acceptable to the Air Force. I do not think E-Systems understands DARPA's mission or role in the DOD R&D structure; nor do I think they have understood what DARPA was trying to accomplish with the GaAs Insertion Program. I believe they have been given some bad advice and as a consequence, have made some bad decisions regarding their GaAs insertion project. I recommend that DARPA not invest additional funds in this project unless both the Air Force and E-Systems are willing to cost-share in the project.

Attachment: Det. 2/DARPA Briefing

cc: Arati Prabhakar

## GRUMMAN VISIT FACT SHEET

### Background

Grumman Aircraft Systems was selected by DARPA to develop an GaAs upgrade to the radar system of the E-2C carrier-based patrol aircraft

The contract between Naval Air Systems Command and Grumman was signed September 18, 1989 for a seven month Feasibility Study. Contract value is $301,700 and covers the period Sept 18, 1989 through April 18, 1990.

The Navy technical monitor for the effort is PMA231, CAPT Sprague, CDR Ekstrom, and CDR Dietz. Rick Pickering of AIR5116C3 is also involved.

Assuming the Feasibility Study is favorable a three-year design and laboratory demonstration program is planned to begin as soon as possible after April, 1990. A three-year pre-production and qualification program would commence after successful laboratory demonstration.

Original Grumman estimate for a 36 month program (assume the three-year design and laboratory demo) was for $9,525,000.

Original planning called for $300,000 study effort in FY89 (funded), $3,200,000 in FY90, and $5,800,000 in FY91.

Grumman has indicated they will cost-share to the tune of $500,000.

### Progress To Date

Based on Bi-Monthly Progress Report, November 18, 1989

Accomplishments

Due to initial staffing/start-up problems, program is one month behind schedule (contract was signed Sept 18, work did not begin until Oct 18). This does not appear to a problem in meeting the April 18, 1990 completion deadline.

The following has been accomplished:

(1) Adaptive displaced phase center antenna transfer function has been reviewed;

(2) Inline complex 3-tap transversal filter has been defined;

(3) Skew doppler processor target models have been defined;

(4) Preliminary math models have been defined;

(5) Previous work during proposal stage on system conceptual design has been reviewed:

(6) Five weapon replaceable assemblies (WRA) have been identified that require modification for the pre-production and qual phase;

(7) Preliminary estimate of the magnitude of the changes has been made for (6) above;

(8) Preliminary design estimates for floating-point adder/subcontractor and fixed point multiplier speed, size, and power using GigaBit Logic macrocell libraries have been determined;

(9) All engineering drawings of the applicable WRAs have been ordered and some for WRA-47 and -49 have been received;

(10) Hardware project engineer visited Vitesse and GigaBit Logic week of November 13, 1989;

(11) Board thickness and slot pitch for existing WRA-49 board format have been determined.

To Be Accomplished

(1) *Filter coefficient array* processor algorithm is to be selected;

(2) Memory management scheme for the Skew Doppler Processor has to be defined;

(3) Analysis of the Skew Doppler Processor velocity detection algorithm has been started;

(4) Assume that final system conceptual design is yet to be completed (unclear in report);

(5) Final choice of fixed point versus floating point is to evaluated;

(6) Initial GaAs chip estimates (type and number) are being reviewed and revised as algorithm development progresses;

(7) Information from (6) above will be used to develop board/box design strategies;

(8) Thermal resistance of GaAs chips is being considered in conjunction with data received from GaAs vendors;

(9) Must determine the complexity and power issues for Grumman functions using the programmable filter processor chip and complex magnitude chip (from Vitesse and GigaBit ?) as benchmarks;

(10) Investigating the existing WRA-47 and -49 enclosures and boards for form and fit requirements to be met by insertion;

(11) for WRA-49 board format, the following must be determined:

(a) Use of the same printed wire board design and format;

(b) Current board I/O is 150 pins. Is there another standard and adaptable connector with more pins? Strategies for design partitioning for implementation to reduce board I/O are being investigated;

(c) Currently boards are cooled by conduction to heat exchanger. GaAs chip power could exceed current board heat dissipation levels for the computationally intensive boards; this needs further investigation and design

(12) Estimates for modification costs to be done.

Based on Update Received December 20, 1989

Accomplishments

GaAs Radar Signal Processor -- fundamental arithmetic building blocks have been designed. Mechanical and thermal designs for WRA-49 and -47 are underway and trade-off alternatives have been defined.

System Design -- Algorithm development and simulation for adaptive displaced Phase Center Antenna and Skew Doppler Processing are underway. Preliminary results indicate better performance than predicted in the proposal. Schedules and SOWs for production are being developed.

Plans for Next 12 Months

Complete the cost and schedule impact evaluation. Initiate chip development, I/O design, filter design, data management design, non-GaAs mods, and continue system algorithm development and simulation. Initiate E-2C system test laboratory mods. Continue mechanical and thermal packaging design.

# APPENDIX 3

## Fact Sheets

Under this contract, Booz•Allen both provided general systems information to DARPA as well as assisted with writing of press releases. To faciliate these tasks, fact sheets were developed on a number of the systems which were candidates for GaAs insertion projects. Samples of this work follow.

## V-22 Osprey

Description: Bell is teamed with Boeing Helicopter Company in a joint program to meet the US government's Joint Services Advanced Vertical Lift Aircraft requirement, with a tilt-rotor aircraft named V-22 Osprey. The US Navy and US Air Force are currently participating in the program, with the USN as executive service.

The V-22 Osprey has been conceived as a multi-mission aircraft. The US Marine Corps, which will receive the first production examples, has a requirement for 552 assault transport variants, designated MV-22A, to replace CH-46 and CH-53 helicopters. The MV-22A is required to carry 24 combat-equipped Marines at a speed of 250 knots over an operational radius of 200 nautical miles. The Navy has a requirement for up to 50 combat search and rescue aircraft, designated HV-22A, to replace HH-3 helicopters. The Navy has also expressed an interest in up to 300 SV-22s for anti-submarine warfare, carrying dipping sonar, sonobuoys, and torpedoes. Long range planning calls for a production decision in FY89 leading to initial deliveries to the Marine Corps by December 1991.

The Air Force requires 80 long-range special operations aircraft, designated CV-22A, to carry 12 special forces troops or up to 2,880 lb of internal cargo over a 700 nautical mile mission radius.

Programmatics: The Army originally was to purchase 231 Ospreys for combat support and medivac missions. This accounted for roughly 25% of planned tri-service procurement. The Army has decided that it cannot afford its planned purchase, and has withdrawn from further participation in the program. Loss of the Army's buy is expected to increase unit costs by an estimated $1 million.

The Navy recently decided to delay development of the Osprey and to put off a development decision on the SV-22 by at least a year in an effort to study sensor requirements. With 300 production aircraft at stake, the Navy's decision on the SV-22 is highly critical to the overall affordability of the program. Currently, DoD has reversed the Navy plans to delay development of the Osprey and has requested $335.3 million in FY89 for advance procurement. (The delay in the SV-22 decision still stands, however, pending a study being conducted by the Center for Naval Analysis).

The Bell-Boeing team has signed agreements with British Aerospace, West Germany's Dornier GmbH, and Japan's Mitsui and C.Itoh to assess the market for military tilt-rotor technology in those countries. Foreign competition for the Osprey exists in the multi-national Eurofar program, consisting of a consortium of companies from Spain, Italy, West Germany, and United Kingdom, to field a civilian tilt-rotor aircraft by 2000. While foreign and civilian sales could help soften the impact of the Army's withdrawal from the V-22 program, such orders are not considered to be imminent.

## HELLFIRE AGM-114A/B MISSILE

Description: The HELLFIRE missile is a laser-guided, antitank terminal homing modular missile system that uses a semiactive laser terminal guidance and a shaped charge warhead. HELLFIRE has been designed to accept other guidance packages. The modular HELLFIRE can be equipped with either a semi-active laser, imaging infrared, RF/IR or a millimeter wave seeker and an analog or digital autopilot. The AGM-114A is the Army version and the AGM-114B is the Navy/Marine Corps version. The RBS-17 is a Swedish coastal defense version that uses a delayed blast fragmentation warhead for antiship missions.

The HELLFIRE can be guided to a target by a ground-laser designator or a designator on a scout helicopter permitting the firing platform to remain out of line of sight of the target. HELLFIRE is the primary weapon on the Army's AH-64 Apache; it will be used on the AH-1T/J and the UH-60A Black Hawk helicopters. A ground launched version is also being developed. It is also being considered as armament for the OV-10 Bronco and A-10 aircraft, and Lynx II and Agusta 129 helicopters; a digital autopilot would allow the missile to be launched from the F/A-18, AV-8B, and A-6 aircraft. The Army has successfully tested the Aquila remotely piloted vehicle (RPV) as a laser designator for HELLFIRE.

Programmatics: The Army approved the HELLFIRE missile for production in March 1982. The Army inventory requirement for HELLFIRE is estimated at over 48,000 missiles and the Navy's requirement at about 11,000 missiles. A dual source all-up-round producer program resulted in Rockwell International and Martin Marietta becoming producers of the completed HELLFIRE round, missile, and laser seeker during FY84 through a mutual technology transfer.

The Army and Navy did not request any procurement funds for HELLFIRE missiles in FY87 due to budgetary restraints and production problems. The Army did however request $12 million for HELLFIRE product improvements. Sweden's Defense Material Administration placed a $65 million order in June 1987 with RI for 700 HELLFIRE missiles to be used in the RBS-17 Shore Defense System. In FY88 the Army requested $168.4 million for 5,000 missiles. The Marine Corps requested $44.2 million for 1,393 missiles. The Army also requested $24.3 million in FY88 RDT&E funds for HELLFIRE PIP under PE 23802A Other Missile PIP (continued development of Digital Autopilot and Electro-Optical Countermeasures). In FY89 the Army requested $146.8 million for 4,000 missiles and $10.8 million for HELLFIRE PIPs under PE 23802A. The Marine Corps requested $47.6 million for 1,410 missiles. The Army and Navy/Marine Corps use of the HELLFIRE weapon system is expected to continue through the 1990s.

## AN/ALQ-126B

Description: The AN/ALQ-126B is a deceptive elecronic countermeasures system. The AN/ALQ-126B is internally fitted in US Navy tactical aircraft, such as the A-4 Skyhawk, A-6E Intruder, A-7 Corsair II, F-4 Phantom, F-14 Tomcat, and F/A-18 Hornet, and has replaced the AN/ALQ-100. In addition to increased frequency coverage, the AN/ALQ-126 incorporates improved deception techniques, a distributed microprocessor control system to enable the system to be reprogrammed to meet changing threats, and also provides considerable improvements in signal processing.

Programmatics: The US Navy has awarded contracts totalling $406 million for production of the AN/ALQ-126B. Approximately 500 systems have been delivered to date. Production is to continue to reach a total of more than 1100 sets. The system is also in production for other air forces for the protection of Canadian CF-18s and Spanish EF-18s. The Navy received $46.1 million for the AN/ALQ-126B in the FY87 budget. Sanders is delivering units at the rate of 22 per month and is expected to increase production. In June 1988 Sanders received a contract of $40 million for 151 AN/ALQ-126B units with deliveries through October 1991.

The Navy considers the AN/ALQ-126B to be a vital program with a major role in their plans for EW suite upgrades. Although the Navy is planning to install the more advanced ASPJ system* on its F/A-18s, any delay in the production of this system could mean proportional increased requirements for the AN/ALQ-126B. The difficulties that the ASPJ program has been facing makes it likely that the AN/ALQ-126B will remain in the fleet for the foreseeable future.

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* The ASPJ (Airborne Self Protection Jammer, AN/ALQ-165) is the next generation ECM system designed for the Navy's A-6, F-14, and F/A-18 aircraft; the Marine Corps' AV-8B Harrier II; and the Air Force's F-16 Falcon. To date, twelve engineering development models have been delivered. Aircraft integration tests began in 1984 for the F-16 and the F-18. Qualification tests and initial flight tests began in late 1985. Operational test and evaluation is scheduled to be complete in February, 1990 with first deliveries scheduled for 1991. Nearly 1000 systems are expected to be delivered to the Navy by 1996.

# E-2C Hawkeye

Description: The E-2C Hawkeye Airborne Early Warning (AEW) aircraft is a ship-based aircraft that provides the primary air and surface radar search capability for US aircraft carrier battlegroups. The Hawkeye is a twin-turboprop aircraft with a crew of five, including a radar operator, air control officer, and a combat information center officer. The E-2C has a 3-4 hour time on station at a typical mission radius of 200 nautical miles. 17 Active and 2 Navy Reserve squadrons operate the E-2C. Each aircraft carrier normally deploys with 4 Hawkeyes on board.

In its AEW role, the Hawkeye uses its search radar to detect and track airborne contacts in the vicinity of the battlegroup. Long-range detection, automatic target track initiation, and high-speed processing enable each E-2C to track more than 600 targets and to control more than 40 airborne intercepts. Current construction E-2Cs have the AN/APS-138 radar system, which can detect aircraft at ranges approaching 260 nautical miles and cruise missiles in excess of 145 nautical miles. In 1986, the Navy began evaluation of an E-2C with the new Grumman/General Electric AN/APS-145 radar system, able to track more targets, at greater ranges, decrease the effects of jamming, and offer better performance over land. The AN/APS-145 is expected to go into production aircraft towards the end of 1988.

Programmatics: The first of three prototypes flew for the first time on 21 October 1960; these were followed by 56 E-2As which have subsequently been updated to E-2B standard. Production of the E-2C version began in mid-1971. Orders from the US Navy for this version now cover 138 aircraft; 111 of these had been delivered by the beginning of 1987, and it is planned for production to continue at the rate of six per year until the early 1990s. In addition to sales to the Navy, land-based E-2Cs are operated by the US Coast Guard (2), US Customs Service (2), Israel (4), Japan (8), Egypt (3), and Sinapore (5).

Navy plans call for the E-2C to be replaced by the carrier-based Advanced Tactical Support Aircraft (ATSA). Long lead procurement funding for the ATSA is scheduled to begin in 1997. The first six planes will be delivered to the Navy in 1998 with an additional 12 planes in 1999 and 24 in 2000. Until the ATSA enters the fleet in numbers, the E-2C will remain the only AEW aircraft operated by the Navy.

# AN/PRC-104 MANPACK TRANSCEIVER

Description: The AN/PRC-104 is a solid-state micro-miniaturised transceiver (radio) using large-scale integrated circuits (LSI) to provide over 280,000 HF band channels. It uses ground propagation to beam signals up to 20 miles and atmospheric propagation to transmit over thousands of miles when using a sky-wave antenna.

The AN/PRC-104 receiver/transmitter unit (RT-1209/URC) is also used with a 100-watt two-man portable system (AN/PRC-105) and the vehicular and base station systems (AN/MRC-138 and AN/GRC-193, AN/GRC-213 respectively). Hughes is continuing efforts to upgrade and modify existing units with digital electronics and is expanding the tuning and coding capabilities of follow-on variants.

The US Marine Corps, Air Force, Navy, and Army National Guard all use the AN/PRC-104. It is also in service in Sweden, the Middle East, New Zealand, and Spain.

Programmatics: The AN/PRC-104 was produced by Hughes Aircraft Ground Systems Group, Fullerton, Ca., under a $22 million contract in 1974 from the US Naval Electronic Systems Command for 1400 units. Through FY85 Hughes received more than $100 million for continuing development and production of the AN/PRC-104 radio set. In 1986 the US Marine Corps awarded Tadiran a $7.6 million contract for equipment related to the AN/PRC-104 and the Navy ordered 1148 sets from Hughes at a cost of $8.4 million. In all, about 9000 units have been ordered or produced as of 1987. Continued production of an additional 2500 units under a $60 million follow-on order and expected export markets should maintain the AN/PRC-104 production through FY98.

## AN/WSC-3

Description: The AN/WSC-3 is the Navy's standard UHF satellite terminal and line of sight transceiver used on both ships and submarines. It offers AM, FM, FSK, PSK and AM wide-band modes of voice and data transmission.

Programmatics: The AN/WSC-3 began production in 1975. Over 7000 sets have been delivered to the US Navy and 17 allied countries including Australia, Canada, Denmark, Egypt, Germany, Korea, Morocco, New Zealand, Norway, Spain, Turkey, and the United Kingdom. To date, total value of US Navy contracts for the AN/WSC-3 is more than $100 million. Orders from other countries are estimated to total $30 million. The AN/WSC-3 will continue to be procured through the early 1990s.

The Navy position is that the AN/WSC-3 will need replacing in a smaller, lighter form by the mid-1990s, however, a development effort to replace the AN/WSC-3 (V) has not yet been started.

# APPENDIX 4

## Computer Data Bases

Booz•Allen developed several computer data bases under this contract. The first contained relevant background data on each digital GaAs insertion project. This data base included key contractor and government personnel, telephone and address lists, budgets, schedules, and milestones.

The second data base was designed to organize information from a funding questionnaire mailed to all GaAs contractors. These responses were organized into a database and delievered to DARPA MTO staff.

Sample pages of each data base follow.

# GaAs Insertion Database

**Project Title:** Modem for Army AN/PRC-126 Squad Leader's Radio

**ARPA Order Number:** 7039

## General Information

| | | | |
|---|---|---|---|
| **Company Name:** | E-Systems | **Government Agency:** | U.S. Army CECOM |
| **Program Manager:** | Mr. Robert Meyer | **Program Manager:** | Joe Lee |
| **Address:** | ECI Division<br>Box 12248 (1501 72nd St. N.)<br>St. Petersburg, FL 33733 | **Address:** | Hqs. CECOM<br>AMSEL-RD-C3-TR-3<br>Fort Monmouth. NJ 07703-5202 |
| **Telephone:** | 813-381-2000x2524 **FAX:** 813-38-2000x4801 | **Telephone:** | 201-532-0448 **FAX:** 201-532-0456 |
| **E-Mail Address:** | RMEYER@A.ISI.EDU | **E-Mail Address:** | AMSEL-RD-C3-D |
| **Co. Tech. Expert:** | Greg Vaal | **Gov. Tech. Expert:** | Joe Lee |
| **Telephone:** | 813-381-2000x3546 **FAX:** 813-381-2000x4801 | **Telephone:** | 201-532-0448 **FAX:** 532-0456 |

## Contract Information

| | |
|---|---|
| **Contracting Agency:** | U.S. Army CECOM |
| **Contract Number:** | DAAB07-89-C-A045 |
| **Date Contract Signed:** | September, 1989 |
| **Date Work Began (if different):** | July 15, 1989 |
| **Period of Performance:** | 24 months |
| **Funding Amount:** | $2 million |

## Technical Information

| | |
|---|---|
| **Candidate Upgrade System:** | ECM |
| **Platform(s):** | AN/PRC-126 |
| **Subsystem(s)/Component(s):** | MODEM & Frequency Synthesizer- |
| **Chip Type(s):** | Custom, ASIC, OTIS |
| **Number of Chips:** | 56 |
| **Chip Vendor:** | Vitesse |

**Abstract:**

The objective of this GaAs insertion project is to develop an enhanced AN/PRC-126 radio that interoperates with the SINCGARS radio in the non-secure frequency hopping mode. The AN/PRC-126 modulation, demodulation and frequency synthesis functions, presently implemented with analog circuits, will be replaced with digital GaAs and CMOS circuits. Insertion of high-speed digital GaAs circuits will result in eliminating several radio frequncy modules, increasing the reliability and radiation hardening, and eliminating critical tuning components, resulting in better protection of soldiers on the battleground.

Sample of the GaAs Insertion Database

## GaAs Insertion Database

| | |
|---|---|
| **Major Technical Challenge(s):** | Phase I-Replacing Analog Circuitry with Digital Circuitry |
| **Program Phases and Dates:** | Phase I - Develop DDSM, perform a 6 month Demodulator trade study, implement Digital Signal processing Demodulator, and Test Models.<br><br>Phase II - Add RF, Power Supply, and SINCGARS brassboards to complete the enhanced AN/PRC-126 brassboard.<br><br>Phase III - Upgrade the enhanced AN/PRC-126 brassboard to a final configuration for evaluation testing. |
| **Major Milestones:** | Study/Design Completion of Demodulator/March-April 1990 |
| **Funding by Fiscal Year:** | FY 89-441,986; FY 90-1,128,154; FY 91-426,836 |
| **Funding by Program Phase:** | ---- |

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
1400 WILSON BOULEVARD
ARLINGTON, VA 22209-2308

May 21, 1991

MEMORANDUM FOR CONTRACT PROGRAM MANAGERS

SUBJECT: Contract Funding Questionnaire - DUE JUNE 21, 1991

Please gather and provide the funding and expenditure information requested in the attached questionnaire. It is critical to us that you provide your data in the attached format and adhere to the June 21, 1991 deadline. We need this information for two reasons: to process your FY 1992 incremental funds, if any, and to defend against budget cuts based on slow expenditure. It is expected that this request does not necessitate additional effort, above the scope of the contract, on your part. If you feel it does please call me.

If you do not have a specific piece of information, please include your best estimate and note it as such. Dawn Tate or Dan Butler should be able to answer any questions you may have about this request. They can be reached at Booz, Allen & Hamilton, (703) 528-8080 extensions 16 and 18.

The funding questionnaire should be filled out and returned by fax to Dawn no later than June 21, 1991.

Thank you in advance for your timely assistance.

Sincerely,

S. A. Roosild

Sven Roosild
Deputy Director, Microelectronics
Technology Office

# CONTRACT STATUS AND FUNDING QUESTIONNAIRE

**DARPA Program Manager:** Arati Prabhakar

**DARPA Line:** BE21E01100, BE21Y01100

**ARPA Order Number:** 6217

**Contract Title:** Semiconductor Manufacturing

**Contract Number:** F3361588C5448

**Start Date:** September 1, 1988

**Contractor:** Texas Instruments

**Program Manager:** Bob Doering

**PM Phone:** (214) 995-2405

**PM Fax:**

**Address:** P.O. Box 665012
MS 944
13500 N. Central Expressway
Dallas, TX 75265

**Agent:** AFWRDC

**Financial POC:** Steve Moreland

**Fin Phone:** (214) - 995 - 2634

**Fin Fax:** (214) - 995 - 6801

**Fin Address:** P.O. Box 655012
MS 944
Dallas , TX 75265

**Principle Investigator(s):**

**PI Phone:**

**PI Fax:**

**Contract Cost:** $112,543,770

**End Date:** October 31, 1993

| | Sept. 30, 1990 | Dec 31, 1990 | May 31, 1991 or as of: | Sept. 30, 1991 (estimate) | Dec. 31, 1991 (estimate) |
|---|---|---|---|---|---|
| Total Obligated | $23,233 | $26,233 | $37,309 | $37,309 | $40,000 |
| Total Expenditures | $19,745 | $23,343 | $29,809 | $37,000 | $40,000 |
| Non Cancellable Commitments | $1,600 | $2,000 | $2,000 | $1,600 | $1,400 |
| OBL - EXP | $3,488 | $2,890 | $7,500 | $309 | $0 |
| OBL-EXP-NCC | $1,888 | $890 | $5,500 | -$1,291 | -$1,400 |

**If (OBL-EXP-NCC) for December 31, 1990 and/or December 31, 1991 is more than 0, please provide an explanation why the funds were/will be remaining**

1. Mod in work to reduce to $86,000,000
2. Contract is Cost Share 62% / 32%. Numbers represent 68% of total cost incurred



Sample page of funding questionnaire

# APPENDIX 5

## Articles

Dan Butler, Booz•Allen's GaAs Program Manager, co-authored with Vitesse's Al Joseph and Arati Prabhakar, DARPA GaAs Program Manager, the following article, which was published at the IEEE GaAs Symposium.

# DIGITAL GALLIUM ARSENIDE (GaAs) UPGRADES FOR IMPROVED MILITARY SYSTEMS CAPABILITIES

A.S. Joseph
Vitesse Semiconductor Corp.
Camarillo, CA 93010

Daniel H. Butler, Jr.
Booz, Allen and Hamilton Inc.
Arlington, VA 22209

Arati Prabhakar
Defense Advanced Research Projects Agency
Arlington, VA 22209

## Introduction

In 1976 an enthusiastic GaAs engineer at a major aerospace firm, trying to convince a product manager to plan for a GaAs insertion, was shocked to learn that the system he was after had yet to be converted from germanium to silicon. This type of story probably could be told about every emerging technology. The process of insertion is painfully slow; the transistor struggled against the vacuum tube as did silicon against germanium.

Today, the first generation of digital GaAs microelectronics is here: high-yield logic and memory circuits with sufficient integration level and performance for some classes of applications are available from multiple suppliers. Users are beginning to explore ways to exploit digital GaAs in both commercial and defense systems. This paper describes the present state of the technology in detail, including examples of yields and fabrication costs from one of the U.S. commercial vendors. It then focuses on a group of 11 digital GaAs upgrades to fielded military systems that defense systems contractors are demonstrating under DARPA support, with a discussion of the military benefits and cost reduction that these upgrades will provide.

## Current Status of Digital GaAs Technology

Digital GaAs ICs are designed, processed, and packaged like silicon ICs, typically by silicon-trained engineers using nearly identical process equipment, design tools, and workstations. Today, commercially available GaAs components provide up to four times the speed performance at less than half the power for the same device cost as compared to the highest performance commercially available silicon. They are orders of magnitude harder to total ionizing radiation dose and can operate over a much wider temperature range. Because these GaAs ICs typically require only 8 to 11 mask levels, compared to 18 or more mask levels for state-of-the-art ECL and BICMOS, they also offer tremendous potential for even greater performance in future generations.

Figures 1 and 2 examine the progress in yield in one commercial digital GaAs manufacturing line, Vitesse Semiconductor Corp. Today, Vitesse is able to produce chips with complexities of 4,500 gates (16,000 transistors) at yields in excess of 50%. Greater complexity is already planned: 30,000-gate chips should be in production by the time this paper is published. Figure 3 gives a cost comparison between an available GaAs gate array and its ECL counterpart. Because it requires so few mask levels, the GaAs circuit costs less to manufacture, despite the higher wafer cost and slightly higher processing cost for each mask level.

Digital GaAs ICs are available from several suppliers. Commercial companies GigaBit Logic, Triquint, and Vitesse offer a variety of logic chips, ASICs, and memories. Such companies as McDonnell Douglas, Rockwell, and Texas Instruments also have digital GaAs production capability for VLSI circuits. For now, the U.S. digital GaAs industry plays a leading role in global production. A solid merchant market is establishing itself, and the long-awaited "hockey stick" upturn is starting. During this period, it is critical that the United States not lose the dominant role to off-shore onslaught.

## Digital GaAs for Defense Systems: Insertion Trends

Military systems are notoriously slow to exploit new technologies; 15 to 20 years often pass before a new capability is fielded. Such long delays are unhealthy for both user and supplier. Dated technology in the field cannot effectively offset our potential adversaries' numerical advantage. And slow-developing military markets often drive emerging technologies off shore, because small entrepreneurial U.S. companies cannot wait a decade or more for orders.

Digital GaAs technology today is at a crossroads. In the last few years, systems designers have begun to explore digital GaAs. Many companies have one or two engineers who are following the technology and, in some cases, beginning to design GaAs circuits and subsystems. However, if business as usual prevails, the

| CIRCUIT | TRANSISTORS | SIZE (MILS) | DIE/WAFER | LOT YIELD | BEST WAFER | FAB SINCE |
|---|---|---|---|---|---|---|
| 1500 GATE ARRAY | 8000 | 137 X 159 | 176 | 68% | 87% | 5/87 |
| 4500 GATE ARRAY | 16,000 | 280 X 160 | 88 | 51% | 77% | 11/87 |
| 15K GATE ARRAY | 60,000 | 280 X 335 | 44 | 19% | 47% | 11/88 |
| 4K SRAM | 50,000 | 85 X 90 | 420 | 22% | 43% | 5/89 |

Figure 1. Lot and wafer yields for Vitesse gate arrays and memories. Gate array implementations are for customer circuits with 80-90% utilization. Source: Vitesse Semiconductor Corporation.

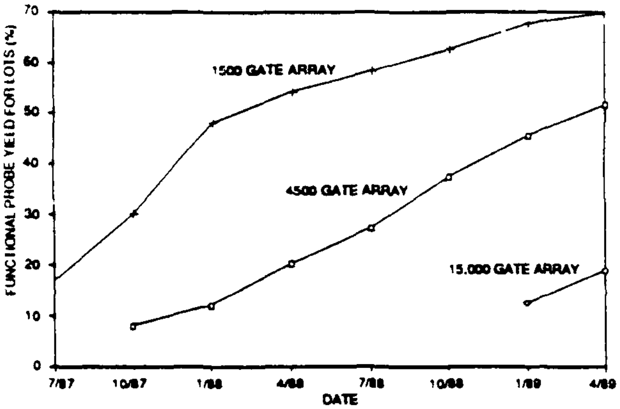


Figure 2. Yield progress for Vitesse gate arrays. Source: Vitesse Semiconductor Corporation.

| | GaAs VSC4500 | Estimated Si ECL |
|---|---|---|
| YIELD | | |
| DIE/WAFER | 160 | 200 |
| WAFER YIELD | 85% | 85% |
| DIE YIELD | 40% | 25% |
| ASSEMBLY YIELD | 90% | 90% |
| TEST YIELD | 85% | 85% |
| PROCESS MASKS | 9 | 18 |
| COST | | |
| WAFER COST | $ 300 | $ 60 |
| PACKAGE COST | 20 | 20 |
| TEST COST | 5 | 5 |
| PROCESS COST PER MASK LEVEL | 50 | 40 |
| COST/PROCESSED WAFER | 750 | 780 |
| COST/YIELD WAFER | 882 | 918 |
| COST/GOOD DIE | 13.78 | 18.35 |
| COST/ASSEMBLED PART | 37.53 | 42.61 |
| COST/GOOD PART | 44.16 | 50.13 |

Figure 3. Cost analysis of VSC4500 GaAs gate array versus an estimate of a comparable complexity commercial ECL array. Source: Vitesse Semiconductor Corporation.

typical 15 to 20 years will pass before most of these initial efforts lead to advanced capabilities in the field.

Through its investments in research and manufacturing, DARPA has played a pivotal role in bringing digital GaAs to its present state of maturity. To overcome the "chicken-and-egg" syndrome and accelerate the insertion process, DARPA last year initiated a new program to upgrade fielded military systems with digital GaAs. Because technology upgrades can often provide substantial performance benefits at a fraction of the cost of developing and deploying a new platform, they are a compelling alternative in a time of shrinking defense budgets. Furthermore, upgrades can accelerate market development by putting new circuits in the field faster than developmental systems.

DARPA asked companies for their best ideas for exploiting currently available digital GaAs in upgrades. Bidders were allowed to select digital GaAs circuits from any viable source, and applications could be in any existing Army, Navy, Air Force or other DoD system. Significant military advantages were sought from the insertion of digital GaAs, e.g., improvements in mission performance, system reliability, or cost benefits. In addition, a major aspect of the selection of projects hinged on the systems users. The Service organization responsible for the system was required to commit to participate in the demonstration; test the prototype; and go forward with qualification, procurement, and installation upon successful demonstration.

Twenty-four companies responded with a total of 43 proposals. Bidders were primarily defense systems companies, and all but four of the bidders had no digital GaAs manufacturing effort in-house. Among them, they proposed using digital GaAs circuits from every U.S. manufacturer. From this group, DARPA selected 11 projects based on technical merit, military utility, the probability of achieving insertion, and the interest of the relevant system program office. Figure 4 lists the projects and the expected systems benefits offered by GaAs. Added capabilities include enhancements in signal and data processing capabilities, radar resolution, jamming efficiency and survivability. Implementing these improvements requires digital GaAs for high speed processing within the power, weight, and volume constraints of the existing platforms.

Several trends emerge from this group of insertions. Some are typical of any new electronics technology:

* To get a significant military advantage from a digital GaAs upgrade, it is necessary to construct a new board or box. While drop-in chip replacements may add some capability, the advantage typically is not substantial enough to justify the effort involved in installing the upgrade.

* Because of compromises that are necessary to accomplish the upgrade, the digital GaAs subsystems that will be constructed in this program will not, in general, represent the state of the art of electronic system capability. Many of the demonstrations will have one or more GaAs technologies working with CMOS and/or ECL circuits, so that level shifting will be required. In each project, specific size, weight, and power restrictions will limit the overall capability. But despite these compromises, digital GaAs can make a substantial difference to the users.

* With few exceptions, companies without internal digital GaAs manufacturing capabilities chose to get ICs from commercial chip vendors Vitesse Semiconductor, TriQuint Semiconductor, and GigaBit Logic. The commercial availability of digital GaAs from multiple sources is very appealing to the user community and should significantly speed the technology's acceptance.

Engineering and business directions analogous to these have emerged for other technologies such as VHSIC. The following are some early trends that are specific to digital GaAs technology:

* The most wide-spread immediate need for digital GaAs in military systems is for microelectronics components that operate as fast as ECL but consume less power. Most of the DARPA insertion projects will provide an electronic function that could be implemented in silicon technology but would require more space, weight, and/or power than is available aboard the platform.

* Despite the fact that GaAs ICs still often cost more than silicon chips, cost savings can be realized at the board or box level. This results from the potential to reduce the number of boards that are needed because the GaAs chips operate faster, or to reduce the packaging complexity because thermal problems are simpler.

| COMPANY | SUBSYSTEM | PLATFORM AND APPLICATION | GaAs PAYOFF |
|---|---|---|---|
| E-SYSTEMS | DISTRIBUTED ARRAY PROCESSOR | AF RC-135 RECON A/C | PROCESS SIX TIMES AS MANY SIMULTANEOUS SIGNALS AT 300 LBS LESS WEIGHT |
| E-SYSTEMS | MODEM AND FREQUENCY SYNTHESIZER | ARMY AN/PRC-126 COMMUNICATIONS | ANTI-JAM FREQUENCY HOPPING; COMPATIBILITY WITH SINCGARS |
| GRUMMAN | RADAR PROCESSOR | NAVY E-2C AN/APS-145 AEW RADAR | 45% GREATER RANGE; 35% SMALLER TARGETS IN CLUTTER; 40% FEWER FALSE TARGETS |
| HONEYWELL | DIGITAL MAP COMPUTER | NAVY/MARINE CORPS TACTICAL A/C NAVIGATION | REAL-TIME MISSION REPLANNING; LOW-ALTITUDE TERRAIN AVOIDANCE |
| ITT AVIONICS | DIGITAL RF MEMORY | ARMY AN/ALQ-136 AIRCRAFT ECM | COUNTER NEW THREATS WITHIN WEIGHT AND POWER CONSTRAINTS |
| KOR ELECTRONICS | DIGITAL RF MEMORY | NAVY ULQ-21 TARGET DRONE ECM | LOWER UNIT COST AND IMPROVED TRAINING REALISM |
| MARTIN MARIETTA | SIGNAL PROCESSOR | ARMY RF HELLFIRE MISSILE SEEKER | LOWER UNIT COST AT REDUCED WEIGHT AND VOLUME; IMPROVED LETHALITY |
| MARTIN MARIETTA | ON BOARD PROCESSOR | SPACECRAFT | INCREASE FROM 75 MOPS TO 560 MOPS WITH NO CHANGE IN SOFTWARE |
| McDONNELL DOUGLAS | IMAGE PROCESSOR | ARMY OH-58D SCOUT HELICOPTER | TRACK-WHILE-SCAN; MOVING TARGET INDICATOR; MULTIPLE TARGET TRACKING |
| SANDERS ASSOCIATES | SIGNAL PROCESSOR | NAVY AN/ALQ-126B TACTICAL A/C ECM | COUNTER NEW THREATS WITHIN WEIGHT AND POWER CONSTRAINTS |
| TEXAS INSTRUMENTS | SIGNAL PROCESSOR | NAVY P-3C AN/APS-137 RADAR | SIGNIFICANT IMPROVEMENT IN ISAR IMAGE RESOLUTION |

Figure 4. DARPA's digital GaAs insertion projects and their benefits to military systems. All improve system performance at lower cost than competing upgrade approaches.

* Today's GaAs logic can solve a multitude of immediate problems very well. However, users tend to find little need for GaAs memory beyond the advantage it may offer when used with GaAs logic to avoid level shifting.

## Cost Savings From Digital GaAs Insertion

As Figure 4 shows, each of the 11 upgrades will add a militarily significant capability to its platform. However, the greatest defense advantage lies in the cost savings that such upgrades allow.

The cost reductions come in many forms. First, upgrading system capability through advanced technology insertion can extend the useful operational life of a system. This means that the initial investment in the system can be amortized over a longer period, and development of an entirely new system can be postponed until other forces — radically changing threat, new mission requirements — dictate a costly new research, development, and acquisition program. Second, the introduction of new technology into existing platforms can mean that fewer of the platforms are needed to perform the existing missions, or that additional missions can be performed with the same number of platforms because of improved performance and enhanced survivability. The realities of today's defense budgets often mean that the required number of systems cannot be acquired even when a program survives the budget cutting process during its R&D phase. Finally, DARPA's digital GaAs insertions demonstrate that in many instances increased system capability can be obtained at lower subsystem cost, so that the upgrades themselves can be accomplished cost effectively.

## Conclusion

While they clearly are not exhaustive of all possible military applications of digital GaAs, the 11 DARPA projects can serve as trailblazers. They address a variety of military application areas, including weapon, communications, intelligence, and electronic warfare systems. In the process of completing the demonstrations, participating companies will build design and test capabilities, interfaces to foundries, and, most important, engineering staffs with experience in digital GaAs. Similarly, DoD agencies will gain experience with the technology and its benefits. This infrastructure will play a vital role in future exploitation. Meanwhile, both commercial and developmental digital GaAs capabilities continue to grow. Companies project 50,000-gate arrays and 64K SRAMs in the next few years. Special circuits — including 200-MHz 32-bit RISC microprocessors, high-speed A/D converters, and dose-rate/SEU hardened parts — will also expand the range of useful devices. These technology and manufacturing advances, coupled with the initial demonstrations of digital GaAs systems capabilities, should open the door for a far greater number of uses for digital GaAs.

# APPENDIX 6

## FORM 298

The required DoD Form 298.

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**6. AUTHOR(S)**
Daniel H. Butler

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
Booz-Allen & Hamilton, Inc.
4001 N. Fairfax Drive
Suite 650
Arlington, VA 22203

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Booz-Allen provided a high level of support, including systems engineering analyses and technical assistance for systems insertion efforts using digital Gallium Arsenide (GaAs). Once insertion candidates were chosen, Booz-Allen supported the insertion efforts by acting as a liaison between the government and GaAs contractors, attending and arranging contractor reviews, providing meeting facilities, and producing presentation materials.

A major accomplishment under this contract was the development of a methodology for appraising the likelihood of a successful technology insertion. This methodology is described in detail. Systems analyses and other work performed according to the terms of the statement of work is described as well. The conclusion discusses accomplishments under this project and of the DARPA digital GaAs insertion program generally.

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